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Specialized University in Logistics

NOFOMA 2015

Post Conference Proceedings

Molde, 3-5 June 2015
Nordic Logistics Research Network

NOFOMA 2015

Towards Sustainable Logistics and Supply Chain Management

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Post Conference Proceedings Editor: Associate Professor Bjørn Jæger

Printing:

Molde University College – Specialized University in Logistics
P.O. Box 2110
NO-6402 Molde, Norway

www.himolde.no/english

Online ISBN: 978-82-7962-207-9

Content

Effects of information sharing on collaboration and logistics performance in emerging economies

Moroccan case study

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ABSTRACT

Purpose

The aim of this research is to examine the information sharing between suppliers and customers and its effects on collaboration and logistics performance of food industry in an emerging economy: Morocco.

Design/methodology/approach

Data collected by using survey research methods from 203 SME. Exploratory and confirmatory factor analyses were done first and structural equation modelling was done for running the conceptual model.

Findings

Information sharing affects strongly collaboration more than logistics performance. In addition, collaboration has a great effect on logistics performance. We can argue that collaboration can be treated as mediator variable of high level of logistics performance.

Research limitations/implications

One of the aim limitations of the current research may have been the nature of scale used. Logistic Performance is formative factors not reflective measures. Moreover, we should distinct those construct into qualitative and quantitative dimensions.

Practical implications

In order to achieve greater logistics performance, more attention should be paid on information sharing as the cornerstone of collaboration then high level of logistics performance.

Originality/value

The research is one of the first studies to examine and confirm the effect of supply chain collaboration on logistic and organizational performance in emerging economies.

Keywords: information sharing, collaboration, logistics performance, emerging economy

INTRODUCTION

The globalization of markets, advances in technology have increased interconnection between countries and companies through the world. In this context, competitiveness requires to optimize the performance of whole supply chains rather than individual organizations (Liker and Choice, 2005, Sheu et al, 2006). Two types of performance are often highlighted: logistics performance and collaboration. In this context, inter-organizational collaboration becomes the cornerstone to achieve high level of performance, (Li et al., 2005).

In the last years, information sharing is a major topic of research in logistics. Studies have dealt with several issues like the conceptualisation of the construct, its antecedents and its consequences. Research made in developed countries confirm that collaborative relationships within the supply chain facilitate access to information (Hsu et al, 2008), share risk (Wagner and Bode, 2008), reduce logistics costs and transactions (Stank et al, 2001), reduce the cost of the product; increase customer satisfaction, strength customer loyalty (Filbeck et al. 2005), improves product quality (Emerson and Grimm, 1998), strengthen the competitive advantage of the firm and finally increase the performance of all firms in the supply chain (Fugate et al, 2010). However, knowledge about information sharing derives almost exclusively from research conducted in United States and Western Europe. Most of the replication studies have also been undertaken in emerging economies because is not yet well investigated; therefore, there is a need to replicate these studies in the emerging economies to compare empirical findings and contribute to the advances on supply chain theory. In other words, it is likely that the information sharing in supply chain concept may not apply in a standard manner in an emerging economy.

The socio-economic, demographic and especially cultural contexts in emerging economies are so different from those in developed countries. Then, the application of theoretical framework and empirical findings in emerging economies becomes less obvious. Burgues and Steenkamp (2006) note that it’s urgent to develop research in emerging markets because success in these markets is crucial for the future of many international firms.

The key goal of this research is to examine the information sharing of key suppliers and its effects on logistics performance and collaboration in an emerging economy: Morocco. According to Hofstede (1997) and Dwairi et al (2007), Morocco can be categorized as high on uncertainty avoidance, power distance, masculinity, and collectivism. A high level of uncertainty avoidance will inhibit innovative responses to changing market environment; a high level of power distance can be detrimental to effective and efficient market response. Further, a high level of masculinity can result into creating market information gap and ineffective market response. Finally, a high level of collectivism may hamper individual motivation and creativity that are essentials for innovative responses to changing market conditions. Moreover, in recent years, the economic activities in terms of contribution to the gross national product and employment have witnessed shift from manufacturing activities to service activities.

According to the previously exposed observations and reflections, we confirm that the environmental context of emerging economies can plays a major role in the understanding and application of information sharing.

As replication, hypotheses in this research are developed on the basis of studies done in western countries. The aim is to verify the relationship between information sharing, logistic performance and collaboration in food industry more to develop new concepts or measuring scales. Therefore, special attention was given to quantitative research. Those industries have a strategic place in the national economy and encompass more than 30% of companies established in Morocco. The public power holders have made great efforts to integrate those sectors in the industrial strategy of the Kingdom especially by targeting more foreign markets, attracting more foreign direct international logistics investment platform and finally engaging

measures within framework of the Pact for Industrial Emergency. Then, interconnections between local and foreign companies become greater.

The rest of the paper is organised as follows: first, we survey relevant literatures regarding information sharing in developed countries and draw conceptual model and the research hypotheses; second, we present the research methodology and results. Finally, conclusions, managerial implications are provided.

1. THEORETICAL FRAMEWORK AND RESEARCH HYPOTHESIS

1.1. Information Sharing

Information Sharing refers to the amount of information relevant, accurate, complete, timely and confidential with partners in supply chain (Sheu et al, 2006). The idea of Information Sharing is that interdependent organizations involved in supply chain might learn from each other's information and may become more responsive to changes in market needs.

Information sharing is considered as the "heart" (Lamming, 1996) "cornerstone" (Stuart and McCutcheon, 1996) "hotspot" (Chen and Paulraj, 2004), "essential condition" (Sheu et al., 2006) of the collaboration between companies involved in the supply chain.

The Global Logistics Research Team at Michigan State University (1995) defines information sharing "the will to make it available between members in supply chain strategic and tactical data such as inventory levels, forecasts, sales promotion…"

Using the multi-case methodology, Ghosh and Fedorowicz (2008) assign that sharing information between retailers and their suppliers helps to build a collaborative relationship over time. Effective communication between companies is the key element of sharing information that enhances understanding of both sides and contributes positively to increased collaboration (Lee and Kim, 1999).

According to Willem (2006), not only the complicating factors surrounding information sharing, but also two characteristics of the shared information itself influence the value of information shared. Generally, three characteristics have been investigated by supply chain optimization studies: source of information, extent of information shared and the quality aspects, like timeliness, accuracy and predictive power. The source of information implies either it comes from upstream (supplier) or upstream (retailer). Only very limited attention is given to the sharing of information coming from the supplier, like cost or capacity information (Chen, 2003). An exception is the study by Chen and Yu (2005); their estimation of the value of supplier's lead-time information shows that as sales volume grows, this upstream information increasingly reduces the supply chain costs. Remind that there is many ways to share information with their suppliers. Often labeled differently with acronyms like Efficient Consumer Response (ECR), Vendor-Managed Inventory (VMI), Continuous Replenishment (CRP), Collaborative Planning Forecasting and Replenishment (CPFR), Quick response (QR), Electronic Data Interchange (EDI), Category Management (CM), Radio-Frequency Identification (RFID). A literature review over the period 2000–2012 done by Montoya-Torres and Ortiz-Vargas (2014) affirm the effect of information sharing on collaboration. Also, information sharing is vital contributor to supply chain performance (Prajogo and Olhager, 2012; Costantino et al, 2014).

1.2. Collaboration in supply chain

The collaboration is a social phenomenon. It was examined by the researchers in sociology, psychology, marketing, management and supply chains management (Min et al, 2005). Also, it was examined in transaction cost economics perspective (Nesheim, 2001) resource-based

theory (Park et al, 2004), Institutional theory, Resource Dependence Theory, the social exchange theory (Thomas and Rangannathan, 2005).

Despite the importance of this concept, collaboration within the supply chain remains an elusive and polysemous concept. This greatly limits the ability of logistics managers to explain and assess the level of collaborative behavior of their partners including suppliers (Saeed et al, 2005).

Several authors stress for the establishment of the relations long-term collaborative between companies at various levels of the supply chain in order to deliver a good value to the customer (Gunasekaran et al., 2001). Nowadays, the collaborative relations are a necessity more than a choice (Matopoulos et al, 2007).

The collaboration within the supply chain means two or several independent companies work together to plan the operations of the supply chain (Simatupang and Sridharan, 2002). It involves the information sharing, resources, and risks (Barratt, 2004). The aim expected in the long term is the realization of the common objectives of the partner companies.

Drawing on the academic literature, supply chain collaboration is a long term partnership in which firms with common goals work closely together to achieve advantage greater than the firms would achieve individually. Data collected by the Supply Chain Council shows that excellent supply chain performance can lower cost by up to 7% and enhance cash-flow by more than 30%. Collaboration, as the critical element, contributes to these performance improvements (Stank et al, 2001). Supply chain collaboration is widely considered by both practitioners and researchers as a vital contributor to supply chain performance (Prajogo and Olhager, 2012).

The collaborative behavior is practices expressed by companies to implement and concretize the collaborative relationships. Our research deals with the collaborative behavior of the key suppliers in morocco as emerging economy.

Authors like Kampstra et al (2006) call back the stages of development of inter organizational relationships: communication, collaboration, intensive collaboration and partnership. We can assert that the communication is the cornerstone of development of best collaborative practices. Mohr and Spekman (1994) point out that the communication is a backbone for the success of the collaborative relationships.

A significant amount of research has focused on the benefits of supply chain collaboration on logistic and organizational performance.

1.3. Logistic performance

The performance is a polysemous concept, multidimensional and can measure it at various levels of the supply chain. This measurement is the cornerstone in the management of the operations by the information which allows the supply chain to take and operate the decisions. “No measure, no improvement” (Kaplan, 1990). In this respect, Harrington (1995) notes that “If you can not measure the performance logistics, we cannot control it and if we can not control it, it would be difficult to manage it and thus we cannot improve it.” More clearly, Keebler and Plank (2009) specify three reasons for which the company has to measure its logistic performance: reduce the costs, increase the turnover and the financial performance and plead for a clear and precise measure of this concept.

Several definitions are very often proposed, accompanied with a measure. The consensus concerning the dimensionality and the measure of the concept has not been achieved. According to Mentzer and Konrad (1991) logistic performance is the efficiency and effectiveness in the realization of the logistic activities Other scholars (Fugate et al, 2010) developed the third dimension like the differentiation. They assert that the customer value resulting from logistic activities also serves as indicator of the performance. They assert that

the logistics can create value by the efficiency, the effectiveness and the differentiation. A superior logistic performance requires superiority with regard to the competitors: Differentiation.

Despite of the lack of consensus between scholars concerning the definition and the measure of logistic performance, agreement seems to be emerging on its effect on organizational performance. Thus, Kluyver and Pearce (2006) remind that the objective of long-term business relationship is to have superior. This requires an implementation of a strategy of the supply chain to integrate and coordinate all the internal processes and the external one in order to offer a superior value to the customer. Also, Rutner and Langley (2000) note that the logistic function plays an undeniable role in the organizational performance.

1.4. Research Model and Hypothesis

Based on previous research presented above, three hypotheses were developed and depicted in figure 1:

H1: Information sharing and collaboration are positively related.
H2: Information sharing and logistics performance are positively related.
H3: high levels of collaboration logistics performance are positively associated with high levels of collaboration.

The research model and hypothesis are depicted in following figure.

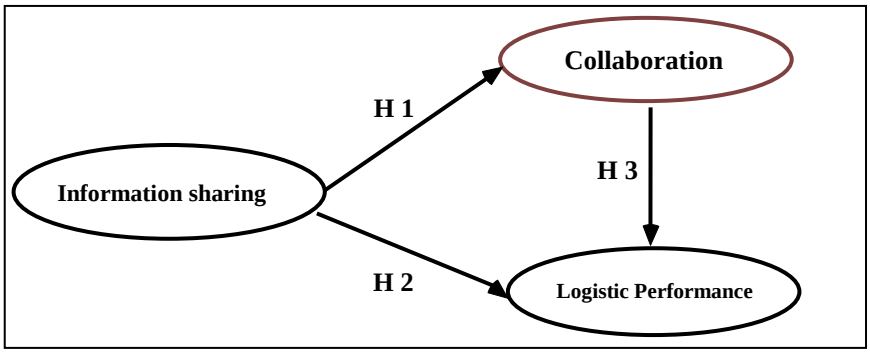

Figure 1 – Conceptual model

2. RESEARCH METHODOLOGY

In order to test the relationships underlying the conceptual model, we have collected data using survey research methods.

Remind that the aim of our research is to test the causal relationships between variables in the model and not develop new scales. For this purpose, we developed a questionnaire following the research done by Cao and Zhang (2011), Cao et al (2010) and used the results of the qualitative study. Thus, 16 items were generated. The scales used by these authors are in English. To dispose of items in French, we followed the methods advocated by Besson and Haddadj (2003): translation English-French and back translation French-English (back translation) in blind by two translators.

Six items were generated to measure the collaboration, five items for the logistic performance and five items for the information sharing. The answering scale used is a seven point Likert scale ranging from 1: totally disagree to 7: totally agree). Moreover, the common pool of items were reviewed and evaluated by practitioners from four different manufacturing firms to pre-assess the reliability and validity of the scales. Two professors specializing in Business to Business Management have also examined the questionnaire. Based on the feedback from the expert, redundant and ambiguous items were eliminated or modified. In total, our questionnaire includes 14 items.

For data collection, we combined different techniques: mailing, personal network, professional associations and mobilized students. Data collection was conducted between September and December 2014 in two major industrial cities of the Kingdom: Casablanca and Tangier. 2600 questionnaires were administered to CEOs, presidents, directors, or logistics managers of food industry. 217 questionnaires were collected. 14 incomplete responses received. Response rate is 8.34%. Finally, data from 203 questionnaires are analyzed.

3. RESULTS AND DISCUSSIONS

To test our conceptual model, we performed a series of exploratory factor analysis (EFA) to check the psychometric quality of the variables and confirmatory analyzes to test hypotheses.

3.1. Results of exploratory factor analysis

An exploratory factor analysis (EFA) by principal component analysis (PCA) with oblique rotation using SPSS 21.0 was done. Two items for collaboration, one item for logistics performance and one item for information sharing were deleted from further analyses because they had factor loading that were lower than the cut-off of 0,5.

The total variance explained was greater than the required merging of 0.6. The reliability assessment of each theoretical construct, before and after removed items, was performed. The result shows good reliability of the data collected for the study; the Cronbach's alphas of each factor were statistically strong; the factor one (collaborative behavior) value was 0,8604, factor two (logistics performance), value was 0,7112, and factor three (organizational performance) value was 0,6869. The results are reported in table 1.

3.2. Results of confirmatory analyzes

Confirmatory analyzes were conducted by using techniques of structural equations (SEM). SEM consists of a measurement model that specifies the relationship between the observed measures and their latent constructs, and the structural model that specifies the causal relationships between the latent constructs themselves (Hair et al, 1998). The implementation of these techniques requires an approach on two-step: first validations of measurement models and then test the structural model as a whole. These analyzes were performed using the software LISREL 8.7.

Validation of the measurement model

After eliminating items poorly represented, we evaluate the overall fit of the models, several fit indices were employed. These included chi-square per degree of freedom, root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), Tucker-Lewis Index (TLI), comparative fit index (CFI), and Root Mean Square Residual (RMR). For GFI, AGFI, CFI, TLI there is a general agreement that the values of .95 or greater indicate a satisfactory fit to the data (Schumacker and Lomax, 2004). The values of both RMR and RMSEA below .08 and .06 respectively represent acceptable model-data fit (Hu and Bentler, 1999). Moreover, for Chi-square per degree of freedom, a value less than 3.0 indicates a reasonable fit.

The results of CFA are displayed in table 2 and 3 and they give evidence for a good fit with the data. However, all items have quite substantial and significant loadings on their respective factor, which indicates the convergent validity of the items. The Average Extracted Variance values for each dimension are well above the recommended threshold of 0,5, thus supporting the convergent validity of the three dimensions. The results of rho of Joreskog show a good reliability for each factor.

	Before the removal of items misrepresented				After the removal of items misrepresented			
Variables	Number of Items	KMO	variance explained %	Alpha de cronbach	Number of Items	KMO	variance explained %	Alpha de Cronbach
Collaboration	5	0,612	53,128	0,5324	3	0,719	73,289	0,6003
Logistics Performance	5	0,705	59,261	0,6035	3	0,644	68,326	0,6283
Information sharing	4	0,479	58,631	0,596	3	0,647	82,261	0,8157

Table 1 - Exploratory factor analysis results for collaborative behavior, logistics and organizational performances.

Variables	Normed χ^2	RMSEA	CFI	TLI	GFI	AGFI	RMR
Collaboration	1,08	0,042	0,937	0,962	0,918	0,983	0,04
Logistics Performance	2,12	0,0491	0,982	0,972	0,927	0,986	0,05
Organizational Performance	2,21	0,0418	0,984	0,918	0,959	0,972	0,04

Table 2 - Confirmatory factor analysis results

Variables	Rhô of Jöreskog	Average Variance Extracted
Collaboration	0, 592	0,509
Logistic Performance	0,6196	0,5469
Information sharing	0,8214	0,606

Table 3 –convergent validity and reliability

3.3. Discussions

The results of structural model provided acceptable overall fit: chi-square of 138, 23 and degrees of 42. GFI, AGFI, CFI, TLI are respectively 0,96; 0,97; 0,97 and 0,96. RMSEA value is 0,04.

The path diagram and the loadings using LISREL 8.7 are shown in figure 1. The result supports hypothesis 1. The standardized coefficient is 0,67 (t = 12,82), which is statistically significant at the level of 0, 01. Thus, the s information sharing has positive and direct effect on collaboration. Hypothesis 3 is confirmed. The LISREL path coefficient is 0,81 (t=9,29), which statistically good at the level of 0, 01. The collaboration has a strong effect on logistic performance. Hypothesis 2 is not supported at the level of 0, 01, the coefficient is poor (0, 09, t=1, 62) showing that information sharing does not affect the logistic performance.

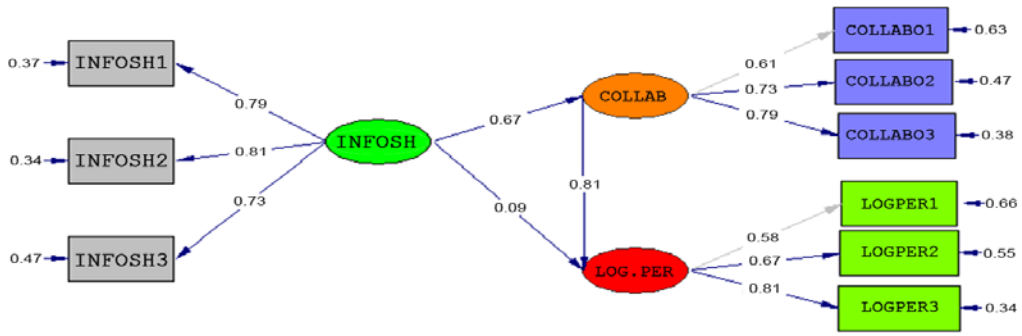

Figure 2 - Hypotheses test using structural equation model (Path and Measurement).

Hypothesis		Coefficients	T value
Information sharing	⟶ Collaboration	0,67	12,82
Information sharing	⟶ Logistics performance	0,09	1,62
collaboration	⟶ Logistics performance	0,81	9,29

Table 4 - Path coefficients and t-values

CONCLUSIONS

The researchers in social sciences plead for the integration of developing economies as breeding grounds of empirical investigation. The majority of the research in logistics were driven in the United States and in Western Europe, now we cannot neglect the emerging countries where lives more than 80 % of the consumers (Steenkamp and Burgess, 2002). In this frame, two main objectives were assigned to this research. At first, verify the mediating role of the logistic performance and then test the effect of the collaborative behavior on the organizational performance in an emerging country especially in Morocco. The empirical study was realized with a sample of 203 companies operating in the agro food sector. The results show that the collaborative behavior has more considerable effect on the logistic performance. We can indicate that the evaluation of the logistic performance should be based on indicators others than quantitative such as the quality of the logistic departments in

particular for the fresh food-processing products. Also, a good logistic performance which is the cornerstone of the organizational performance bases on the collaborative behavior of the suppliers. Thus, an improvement of the relationship quality with the suppliers of the inputs (Raw materials, price, deadline and conditions of delivery.etc) through regular visits is important. So, the division of the knowledge, the role of information systems (Entreprise Ressource Planning ERP, Advanced Planning System APS, Supply Chain Execution SCE and the integration and the Electronic Data Interchange EDI) are the cornerstone for a good management of the relation supplier. The results imply managerial implications for companies from emerging and developed countries.

This research shed light on the perception and applications of collaborative behavior in Morocco. The results are highly useful for the Moroccan companies as well as for their partners in the western countries. Besides, Moroccan presents attractive site for foreign investment together with strong traditions of business with Europe. In this respect, interactions exist between western companies and Moroccan ones and are characterized by different level of collaboration.

While the research has made significant contributions to research and practice, there are limitations that need to be considered when interpreting the study findings. They offer perspectives for future researches. Choices done in the measure of variables, we were inspired by works of Cao and Zhang (2011), Cao et al (2010). This concept measure was tried in contexts different from the food-processing industry and the sector of the textile and the leather. The use of measure developed by other scholars could possibly modify the results of our research. We supposed that the logistic performance and the organizational performance are two reflective indications that authors (Fugate et al, 2010) Consider that they are formative.

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Business Development of 3PL Providers
A multiple case study research in Germany

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ABSTRACT

Purpose
The third party logistics (3PL) industry is characterized by a high market growth potential for the providers. However, 3PL providers are challenged with increasing competition, declining profit margins and high costs of new business acquisition. Formalization and professionalization of business development (BD) is required to exploit the market potential more efficiently and effectively. This research aims to describe a first conceptual framework of the research field of 3PL providers' BD not yet investigated.

Design/methodology/approach
For 8 semi-structured interviews conducted with managers responsible for BD, sales or marketing of 3PL business in Germany, the exploratory case study research was applied to describe the understanding, organization and process of BD.

Findings
Different types of organizational integration of BD have been identified: BD as its own enterprise function, as an activity performed by other functions or as a corporate philosophy. BD can also be clustered into reactive and proactive process approaches.

Research limitations/implications
By a qualitative analysis, a first conceptual framework of BD has been developed. In order to show cause-effect relationships between structures and practices of BD and performance, further research is needed.

Practical implications
3PL providers can obtain more transparency about the nature and process of BD and implications on how they can work their market.

Original/value
The paper describes the research field of BD of 3PL providers not yet examined and relates it to logistics innovation management and service development.

Keywords: third party logistics, logistics service providers, business development, sales, logistics innovation, service development, case study

1. INTRODUCTION

The third party logistics (3PL) industry is characterized by one of the highest market growth potentials for logistics service providers in comparison to other logistics segments due to the ongoing trend of outsourcing (Hertz and Alfredsson, 2003; Lieb and Lieb, 2012; Kille and Schwemmer, 2013; Langley *et al.*, 2015). However, the providers are challenged with rising competition, declining profit margins and increased requirements of 3PL buyers to higher levels of complexity and precision while tender success rates are low and costs of new business acquisition are high (Berglund, 1999; Wrobel, 2014). As a result, it is important for 3PL providers to understand their options for expanding their business (Soinio *et al.*, 2012) and to excel from their competitors by developing and selling customized and innovative services in a more efficient and effective way (Lieb and Randall, 1999; Flint *et al.*, 2005).

Business development (BD) or, in other words, the ability to generate new business for growth (Koppers and Klumpp, 2009) is a concept which is critical for today's business success (Karol *et al.*, 2002) and can help in finding solutions for these 3PL market challenges. Relating to BD, different strategies which support business growth are discussed: market penetration, service development, market extension and diversification (Ansoff, 1965; Scheuing and Johnson, 1989). The operational realization of these strategies includes, on the one hand, the development, enhancement and improvement of services, on the other hand, marketing and sales in order to gain business (see e.g. Newman, 2011).

The scientific publications on 3PL are increasing due to the ongoing trend on outsourcing logistics (Leuschner *et al.*, 2014), however, BD is not yet investigated. Furthermore, a lack of research on marketing and sales of logistics services in general has been determined by Busse and Wallenburg (2011). A more recognized subject area in logistics research is innovation management (Su *et al.*, 2011) as the development of new logistics services (Flint *et al.*, 2005). But the exploitation of this potential to win new business is not described. The fact that previous research avoids reference on the subject of BD demands a first conceptual framework on 3PL providers' BD.

Since BD of 3PL providers is not yet examined in the scientific literature, the objective of our study is to gain a first understanding on how BD is defined and realized by 3PL providers. We geographically focus on Germany as it is one of the most important 3PL markets in Europe (Kille and Schwemmer, 2013). More specifically, we aim to answer the following two research questions:

- RQ 1: How is BD defined by 3PL providers?
- RQ 2: How is BD organized and what do the process of BD look like?

The article is structured as follows: In section 2 an introduction to 3PL is given followed by an overview on the research field of BD. In Section 3 we examine the status quo on BD of 3PL providers in use of a literature review in leading logistics journals. In section 4 the methodology and findings of the case study analysis in Germany are presented. The study concludes with a discussion of the findings, managerial implications and future research suggestions in section 5.

2. THEORETICAL BACKGROUND

2.1. 3PL as contract logistics services business

Research on 3PL is increasing since the late 1980s (Ashenbaum *et al.*, 2005; Leuschner *et al.*, 2014). Over time, a variety of different interpretations and definitions of 3PL were developed in the literature (Knemeyer and Murphy, 2005; Leahy *et al.*, 1995; Marasco, 2007). There are broad and narrow definitions depending on the research aspect or perspective of the author and the geographic location (Prockl *et al.*, 2012; Selviaridis *et al.*, 2008; Skjoett-Larson, 2000). As a result, the research in relation to the terminology of 3PL is not always consistent (Van Laarhoven *et al.*, 2000). In a broader understanding, Ellram and Cooper (1990) define 3PL as services which are performed by external providers. In this context, basic logistics services as transport or warehouse operations are referred to as 3PL. A narrow interpretation of 3PL is given by Murphy and Poist (1998, p.26). They define 3PL as "[…] a relationship between a shipper and third party which, compared with basic services, has more customized offerings, encompasses a broader number of service functions and is characterized by a longer-term, more mutually beneficial relationship". In the frame of 3PL, the term "contract logistics" is also discussed (Sink and Langley, 1997). Klaus *et al.* (2011) characterize contract logistics as services which combine several logistics functions to a complex and customer-oriented service bundle, which are contractually defined between providers and customers in the sense of a longer-term business relationship and which refer to a significant business volume (see also the discussion of 3PL and contract logistics characteristics by Prockl *et al.*, 2012). In this study, we follow the understanding of Klaus *et al.* (2011) and consider 3PL as a contract logistics services business from the providers' perspective.

2.2. Business development from a systemic and procedural view

BD is examined from a systemic and procedural view in our study. The systemic approach (oriented at the general system theory originated by Bertalanffy, 1968) examines how BD is defined and integrated in the organization of a company. This includes the understanding and organizational integration of BD. The business process defined by Davenport and Short (1990, S. 11) as "[…] a set of logically-related tasks performed to achieve a defined business outcome" of BD is operated in this system. Independently of structures and responsibilities, the process approach analyzes how BD activities are performed. Our following research on BD especially of 3PL providers is oriented on the four pillars of organizations which have been related to BD by Van der Merve (2002): strategy, structure, process and projects. The understanding, organizational integration and procedural implementation of BD in general is described below and gives us a structure for further analysis.

Understanding of business development

BD is a term which is frequently used but not clearly defined in the business environment (Kind and Zu Knyphausen-Aufseß, 2007). In the scientific literature, the definitions range from operational sales related objectives to strategic decisions of doing business. However, they all have in common that through BD new opportunities for growth are analyzed and if it is worthwhile realized (Koppers and Klumpp, 2009). Based on the product-market-matrix of Ansoff (1965) (transferred to services by Scheuing and Johnson, 1989) different opportunities for services business growth exist:

- market penetration: selling more existing services to current customers,
- service development: developing new services and marketing to existing buyers,

- market extension: offering existing services to new customers and
- diversification: entering completely new territories in developing new business.

Within this context, different research streams of BD could be identified: new service development (NSD), new business development (NBD) and customer business development (CBD). NSD as the development and introduction of new services is a key competitive factor in the services industry (Johnson *et al.*, 2000; Stevens and Dimitriadis, 2005). The term new services includes improvements and extensions of existing services as well as new service offerings for existing customers and major innovations (Cowell, 1988). Kuester *et al.* (2013) state that NSD activities vary according to different segments of the services industry (e.g. bank services, telecommunications or logistics services) and therefore suggest to be considered individually (see Zhou and Wang (2012) for an analysis of NSD in logistics enterprises). Furthermore, NBD especially focuses on developing business beyond the existing boundaries of a company (Karol *et al.*, 2002; Daubenfeld *et al.*, 2014). These new business opportunities are also referred to as major or radical innovations (Berends *et al.*, 2007). CBD refers to creating value by developing the business customer's business (Hunter, 2014). In this approach the needs of key customers are integrated in the planning, selling and implementation of companies' new solutions.

Organizational integration and procedural implementation

Organizational structures are used to coordinate work that has been divided into smaller tasks and are designed differently depending on the business strategy followed (Olson *et al.*, 2005). The alternative types of organizational structure (e.g. functional or matrix) in which BD is operated have a different impact on the realization of strategic decisions and activities of BD (Van der Merwe, 2002). BD has many interfaces with other functions and employees within the company (e.g. marketing and sales) and also outside the company with the customers' employees (Daubenfeld *et al.*, 2014). Apart from the organizational integration of BD Pearson (1976) and Van der Merwe (2002) agree that BD in the sense of strategic planning and decision making has to be project oriented. A procedural and more operational view on BD can be represented by Newman (2011) and Nutt (2007). In this context, not only the strategic planning, but also marketing and sales plans, tender evaluation and preparation, proposal development and negotiation of the contract for winning new business is part of the BD process (see Figure 2.1).

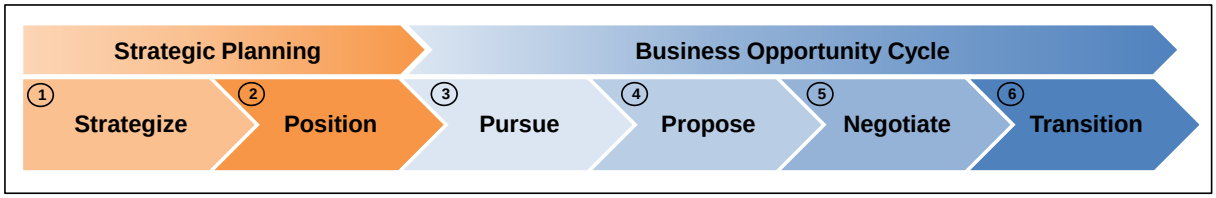

Figure 2.1 BD lifecycle (following Newman, 2011 and Nutt, 2007)

Steps one and two of the BD lifecycle are linked to strategic planning and positioning and therefore take place less frequently than the more operational steps three to six which are repeated regularly for each business opportunity: pursue of business opportunities, proposal preparation, contract negotiation and transition.

3. LITERATURE REVIEW

At the beginning of every research, the status quo of the previous work is analyzed (Ashenbaum *et al.*, 2005). In our literature review, we follow the stages of research synthesis proposed by Cooper and Hedges (1994). The focus is on identifying the status quo on BD of 3PL providers including the understanding of BD as well as organizational and procedural approaches. The EBSCO database is used for the literature search. Publications in academic journals written in the English language until December of 2014 are scanned. A selection of leading logistics journals based on established journal rankings and further literature reviews (Busse and Wallenburg, 2011; Harzing, 2014; Leuschner *et al.*, 2014; Maloni and Carter, 2006; Schrader and Hennig-Thurau, 2009) are used to accomplish the search, see Table 3.1. The search terms are derived from the literature which was input for the theoretical background. They are only listed if they are defined in the database. The defined terms have been searched in title, keywords or abstract of a publication. The relevance of the identified articles has been determined by two researchers in regard to the focus of the literature review.

Table 3.1 Literature review on BD of 3PL providers

Journals	Search terms	Identified research topics
International Journal of Logistics Management, *International Journal of Physical Distribution & Logistics Management*, *Journal of Business Logistics*, *Journal of Supply Chain Management*, *Transportation Research: Part E*, *Supply Chain Management: An International Journal* and *Transportation Journal*	"development", "innovation", "commercialization", "marketing", "sales", "acquisition", "contract", "selling" and "offering"	Innovation management, understanding buying behavior and process, contractual agreements, 3PL relationships, segmenting 3PL offerings, product development and commercialization in the supply chain and marketing and selling logistics value

In total, 39 publications have been identified. More than half of the articles have been found by using the terms "innovation" and "contract" following by "marketing". Exceedingly few articles are relevant with the search term "sales". The content of the identified articles can be categorized in different topics, see Table 3.1.

Innovation management of logistics service providers is the most prominent cluster (see e.g. Busse, 2010; Busse and Wallenburg, 2011; Chapman *et al.*, 2013; Grawe, 2009). Therefore the three aspects of our research understanding, organization and process are considered in the following. In this context, innovation is defined as logistics related services that are new in that they are different to the providers' offerings of the past and create greater value to the customer (Flint *et al.*, 2005; Rossi *et al.*, 2013). These customer-related external innovations can be differentiated into two types (Bellingkrodt *et al.*, 2013; Wallenburg, 2009): new services for potential business with new customers and improvements in ongoing business relationships with existing customers. Daugherty *et al.* (2011) examine the effect of the three

elements of organizational structures formalization, centralization and specialization on logistics service innovation capability. The process of generating logistics innovation is described by Flint *et al.* (2005). The iterative process includes four main groups of activities: setting the stage, customer clue gathering, negotiating, clarifying and reflecting as well as inter-organizational learning. Furthermore, logistics service providers have two opportunities in generating innovations and especially improvements. The first being a reactive response on customers' requests, the second being proactive in exploring new opportunities for customers (Wallenburg, 2009).

In a second cluster, the authors of the relevant articles analyze the buying behavior and logistics outsourcing process of potential customers in order to obtain better insights for the providers (e.g. Maltz and Ellram, 2000). The process of buying logistics services proposed by Sink and Langley (1997) includes five not strictly sequential steps: identify need to outsource logistics, develop feasible alternatives, evaluate and select provider, implement service and ongoing service assessment.

Other authors examine in their research design, content and effectiveness of contractual agreements between providers and customers of logistics services (e.g. Forslund, 2009; Sankaran *et al.*, 2002). The contract is essential for both providers and customers due to the impact on design and management of 3PL business relationships (Olander and Norrman, 2012). The status quo of 3PL services pricing is analyzed by Lukassen and Wallenburg (2010).

Other identified topics are determinants of successful 3PL relationships (e.g. Large *et al.*, 2011; Leahy *et al.*, 1995; Knemeyer and Murphy, 2004), segmenting of 3PL offerings (e.g. Prockl et al., 2012), product development and commercialization (e.g. Rogers *et al.*, 2004) and marketing and selling logistics value (Andraski and Novack, 1996; Lambert and Burduroglu, 2000).

In general, a lack of research on BD of 3PL providers can be determined in the context of this literature review. Especially sales of logistics services and acquisition of new customers is a research field not yet examined. This is also confirmed by Busse and Wallenburg (2011). No publication refers to the term "business development" itself. Also, by searching the term "business development" in the whole EBSCO database in combination with the terms "3PL", "third party logistics" and "logistics service providers", no relevant result could be identified. While the term is present in the 3PL practice (see the market studies of Helmke and Jung, 2007 or Langley *et al.*, 2015), the scientific logistics related literature avoids reference to BD. Therefore, a first analysis of BD of 3PL providers in Germany could enhance transparency for both research and practice.

4. CASE STUDY ANALYSIS

4.1. Methodology: exploratory case study analysis in Germany

Since hardly any research on BD of 3PL providers was found, an exploratory case study approach has been chosen to generate a first understanding of business development of 3PL providers in Germany. Eisenhardt (1989) states that especially the usage of case study research is appropriate in early stages of research on a topic. Yin (1994) differentiates three different types of case studies: exploratory, descriptive or explanatory. In this context, we apply the exploratory case study approach which is especially used to explore an issue with limited empirical results and theoretical frameworks. Furthermore, we decided to follow a multiple case design that follows for comparison of the results in sense of showing similarities

and highlighting explainable contrasts in order to develop a theoretical framework for further research (Ellram, 1996). In the research field of logistics and 3PL several authors (e.g. Frankel *et al.*, 2005; Maloni and Carter, 2006; Näslund, 2002) confirm an ongoing need for qualitative methods and case studies to gain a deeper understanding of the formation of 3PL business. Our case research design as described below is oriented on Yin (1994).

In order to find answers to our research questions, multiple cases have been selected using the convenience sampling approach (Bass, 1990). First of all, we have selected the German business environment of 3PL because of its market relevance: Germany is the largest logistics market in Europe with a volume of 230 billion € (Kille and Schwemmer, 2013). This represents approximately 25 % of the European logistics market with a total volume of 930 billion €. Furthermore, the 3PL market is the largest logistics market segment in Germany with a volume of 91 billion € and not more than 28 % of this volume is outsourced to 3PL providers (Kille and Schwemmer, 2014). Besides that, the cases should also represent different sizes in terms of generated yearly 3PL revenues and different degrees of specialization in doing 3PL business in comparison to other business areas for example transportation. We have found eight different logistics service providers with different size and specialization on 3PL business in Germany who are willing to participate (see Figure 4.1): from very small and not specialized over medium-sized and specialized to international leading logistics companies on 3PL business. This should reflect the business environment of 3PL providers in Germany adequately and helps in generalizing the findings.

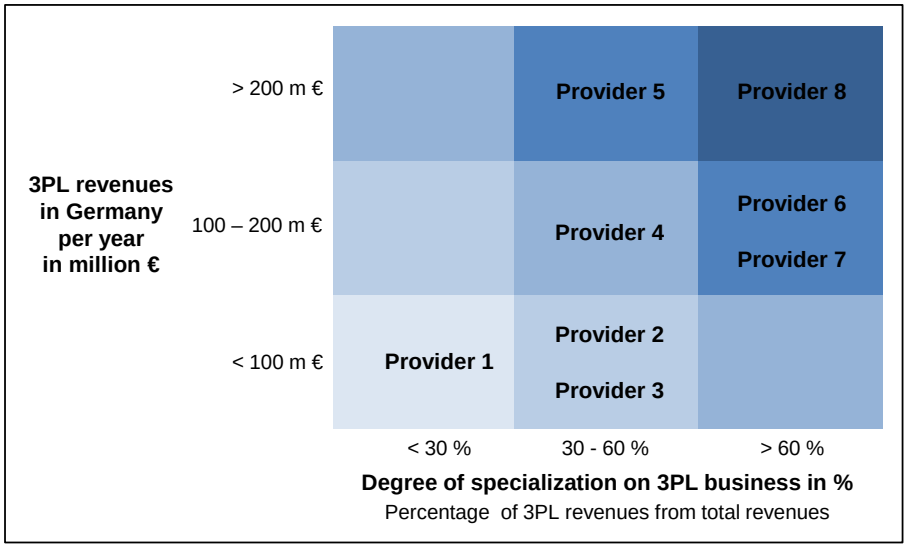

Figure 4.1 Selected cases of 3PL providers

The data collection includes eight semi-structured interviews (see Appendix for the interview guide) conducted with managers responsible for business development, sales or marketing of 3PL business in Germany. In comparison, Yin *et al.* (1976) propose six to ten cases to provide compelling evidence. The length of the personal telephone interviews ranges, per case, from half an hour up to one hour. The interviews were recorded and for each case study a protocol was prepared based on questions of the interview guide. These within-case descriptions were validated by the respondents. In addition to the interviews, we collected multiple data of the participants' organizations and job descriptions in purpose of triangulation (Yin, 1994). Furthermore, the data analysis included a cross-case search for patterns in understanding, organizing and procedural realization of 3PL providers' BD. In comparison with the theoretical background and literature review of this study, the cross-case findings are presented in the following section.

4.2. Findings: 3PL providers' business development in Germany

First, the strategic understanding of BD of 3PL providers in Germany is presented. After that, we describe the integration of BD in the organizational structure and the interfaces with other corporate tasks and enterprise functions such as sales and tender management. Finally, different process approaches and the operational implementation of BD are discussed.

4.2.1. Understanding of business development

In general, BD is described as the strategic development of business by all the interviewed persons. However, there are different understandings of BD among the respondents. The most frequently used words in terms of defining BD are customers and business areas as well as new and existing. The new service and strategy matrix of Scheuing and Johnson (1989) combines these different terms and gives us a useful structure of four different business strategies for the discussion of these different understandings.

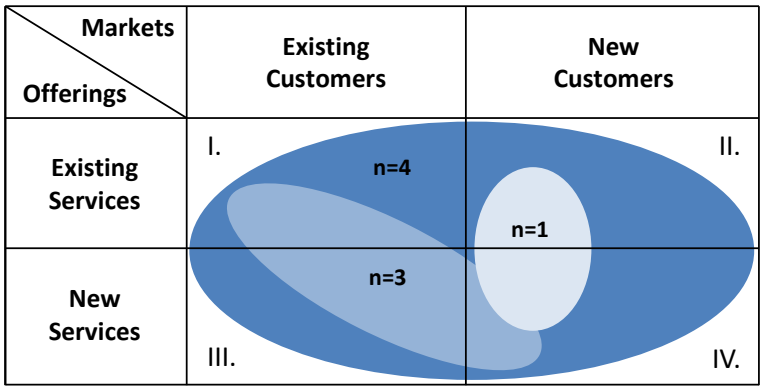

Figure 4.2 3PL business development understanding (following Scheuing and Johnson, 1989)

Half of the respondents understand the whole approach of Scheuing and Johnson (1989) as business development, see Figure 4.2: development of business with new and existing customers as well as with new and existing service offerings. Three out of eight participants describe BD in their organization as the development of new business with new or existing customers. They exclude from their understanding the acquisition of new customers for existing services business. One provider concentrates their BD activities on the development of new customers and markets. As a result, there are numerous ways to develop 3PL business:

- expansion of existing customer business (I.),
- acquisition and development of new customers for existing services (II.),
- mutual creation of new services with existing customers (III.) and
- development of completely new business (IV.).

Finally, in this context, we would define BD as the development and expansion of 3PL services business with existing and new customers. The different by the respondents followed understandings of BD due to the different business strategies chosen by their organizations.

The objectives pursued with BD by the eight providers are primarily business growth in terms of increase in revenue or new customer acquisition. Additional subordinate goals are definition and realization of business strategies, establishment and expansion of competencies as well as finding and operation of market niches. They all agree that BD is highly important for the providers' business success.

4.2.2. Organizational integration

Types of organizational structures

The alternative forms of organizational structure are typically described by three main elements (Olson *et al.*, 2005 and Daugherty *et al.*, 2011): formalization, centralization and specialization. In this context, formalization is demonstrated by the presence of a department and clear rules and procedures for business development. The involvement of the highest management levels (e.g. general manager) in the general decision making process for new customers and services is reflected by a high degree of centralization. Specialization is shown by specific BD skills and experiences (e.g. 3PL or specific industry know-how) of the staff.

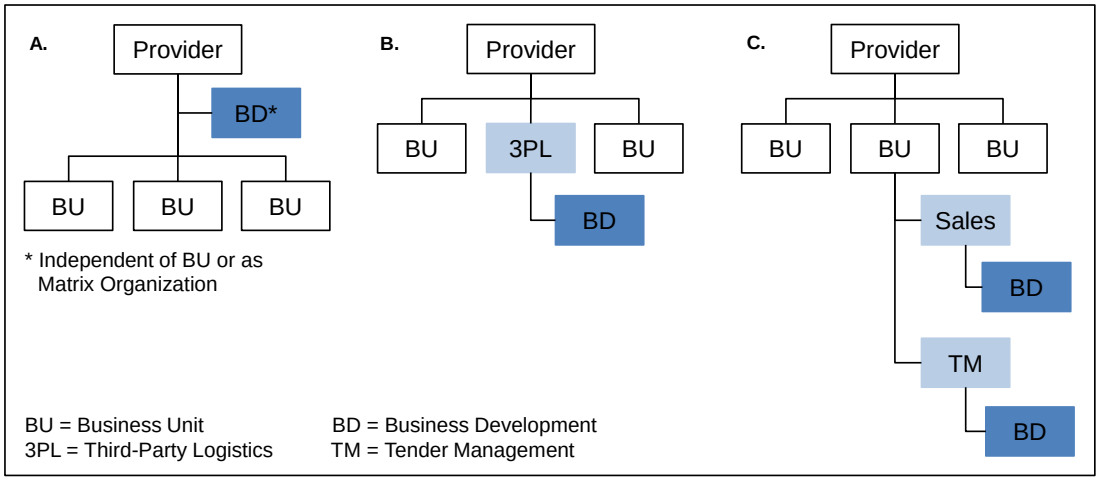

Figure 4.3 3PL business development types of formalized organizations

Three different types of formalized BD organizations have been identified, see Figure 4.3:

- BD as a central unit (A.),
- BD as an enterprise function of the 3PL business unit (B.) and
- BD as part or activity of other enterprise functions as sales or tender management (C.).

The central unit of BD can be operating independently of the business units (e.g. automotive, health care, consumer goods) or within a matrix if applicable due to the size of the company. In a matrix organization, BD managers responsible per business unit as well as per geographic business area (e.g. Europe, Asia) can exist besides the general responsible BD manger. The general management of this centralized type of BD organization is often involved in the decision making process. BD as an enterprise function of the 3PL business unit is also characterized by a high level of formalization and centralization. The third type of formalized BD organization is characterized by a moderate degree of formalization and centralization. BD is interpreted as a part or an activity of another enterprise function, mostly sales or tender management. Furthermore, another less formalized type of BD organization could be detected: BD as interdisciplinary task or corporate philosophy of the providers. This fourth type of BD organization involves staff of different enterprise functions such as sales, marketing, key account management, IT or production in terms of BD projects. The initiative of BD originates both from top-down or bottom-up. The specialization of the BD staff is similar along the four types of BD organization. Most of the BD employees have an academic education in business economics or engineering. Besides that, experience and know-how in the 3PL services business are required. Industry-specific (e.g. automotive, health care,

consumer goods) skills can be beneficial especially in larger companies with matrix structures.

Internal interfaces with other corporate tasks

A precise differentiation of BD from other enterprise functions such as sales or marketing is not possible in this study. However, we could identify several internal interfaces between BD and other corporate tasks, see Figure 4.4. The functions or tasks cited in relation to BD most often are sales, tender management, key account management, marketing and general management. Especially in the context of BD as interdisciplinary task additional corporate tasks such as operations or production and IT are mentioned by the respondents.

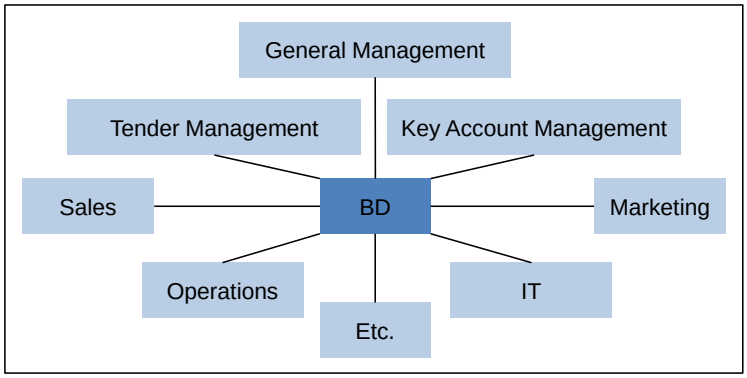

Figure 4.4 Internal interfaces of 3PL business development with other corporate tasks

In a more strategic approach of BD, we could identify the task of BD as a strategic identification and selection of business opportunities which is therefore located upstream from sales and tender preparation. BD in a more operational approach fulfills the tasks of tender management and business implementation beyond the strategic selection of business opportunities (comparable with the understanding of Newman, 2011). Sales have a supportive role in this approach in terms of contacting potential customers. The key account management assumes the customer support after the business transaction and implementation in both approaches. Marketing can be involved in BD tasks in applying or providing the methodical instruments of market analysis and cultivation. The general management is often included in the decision making process.

4.2.3. Procedural implementation

In contrast to organizational structures and corporate interfaces, this chapter analyzes the implementation of the BD tasks in terms of processes. As in logistics innovations (Wallenburg, 2009), we can distinguish between two different process approaches of business development, see Figure 4.5:

- the proactive approach in generating new business opportunities (α.) and
- the reactive approach in responding on customers' requests (β.).

The starting activities of the proactive process approach are strategic planning, top-down target generation (e.g. new markets, customers or regions) by the general management as well as bottom-up idea generation (e.g. customer needs or service improvements) for new business opportunities. In most of the cases these starting activities are followed by a market analysis (e.g. competitors, customers) and a comparison with corporate competencies (e.g. knowledge

of the potential industry and their processes). Subsequently, the new business idea is evaluated and a decision of further pursue is made. If the decision is positive, the required new competencies have to be established and the proactive customer acquisition can be started. The new service development (see e.g. Zhou and Wang, 2012) or logistics innovation generation (see Flint *et al.*, 2005) are not necessarily a part of the proactive process approach. Also, the mere development of new customers and markets with existing services is followed by the 3PL providers.

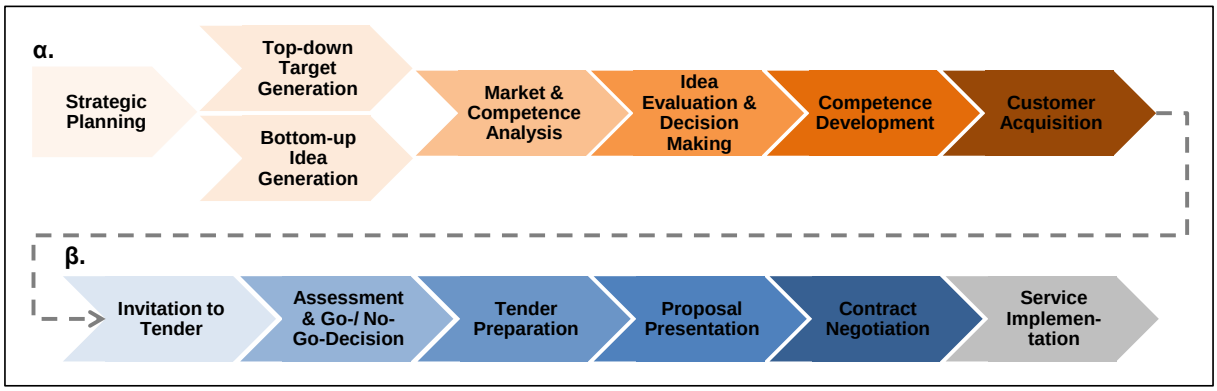

Figure 4.5 Procedural approaches of 3PL business development

The reactive process approach begins with an invitation to tender from a potential customer who has identified the need to outsource logistics (see also Sink and Langley, 1997). In the following step, the incoming tender is assessed and followed by a go- or no-go-decision. In case of a go-decision, the tender preparation in terms of a detailed concept development and design begins. The presentation of the proposal by the provider and simultaneously the concept evaluation by the buyer is the essential next step. If the providers' concept is finally selected by the buyer, the BD process of 3PL terminates after the contract negotiation and conclusion. In few cases, the service implementation and therefore the ramp-up of the 3PL services business is also part of the BD process. A combination of the proactive and reactive approach is also used by the participants of our case study analysis (see also Newman, 2011 and Nutt, 2007).

5. CONCLUDING DISCUSSION

In this paper, we have studied the research field of 3PL providers BD in two different ways. On the one hand, we review the literature and cover the status quo on BD of 3PL providers. On the other hand, we follow an exploratory case study approach to analyze the understanding, organizational integration and procedural implementation of BD in the German 3PL providers industry. In the scientific literature, BD of 3PL providers is not yet examined. In leading logistics journals no single publication was identified dealing with BD. However, the theoretical background shows us individual aspects related to BD of 3PL providers: logistics innovation, new service and new business development as well as customer business development. The case study findings allow a deeper insight in our research field. In this context, we could define BD as the development and expansion of 3PL services business with existing and new customers. Furthermore, we have identified different forms of organizational integration: business development as its own enterprise function, as an activity performed by other enterprise functions - especially sales and tender management - or as an inter-disciplinary task or corporate philosophy of 3PL providers. Besides that, a

proactive process approach, the generation of new business opportunities, and a reactive approach, the respond to customer requests, are described.

As a final theoretical implication we would like to outline a first conceptual framework of BD for 3PL providers in Germany that includes a relation not only to logistics innovations and, in general, business development, but also to our case study findings, see Figure 5.1.

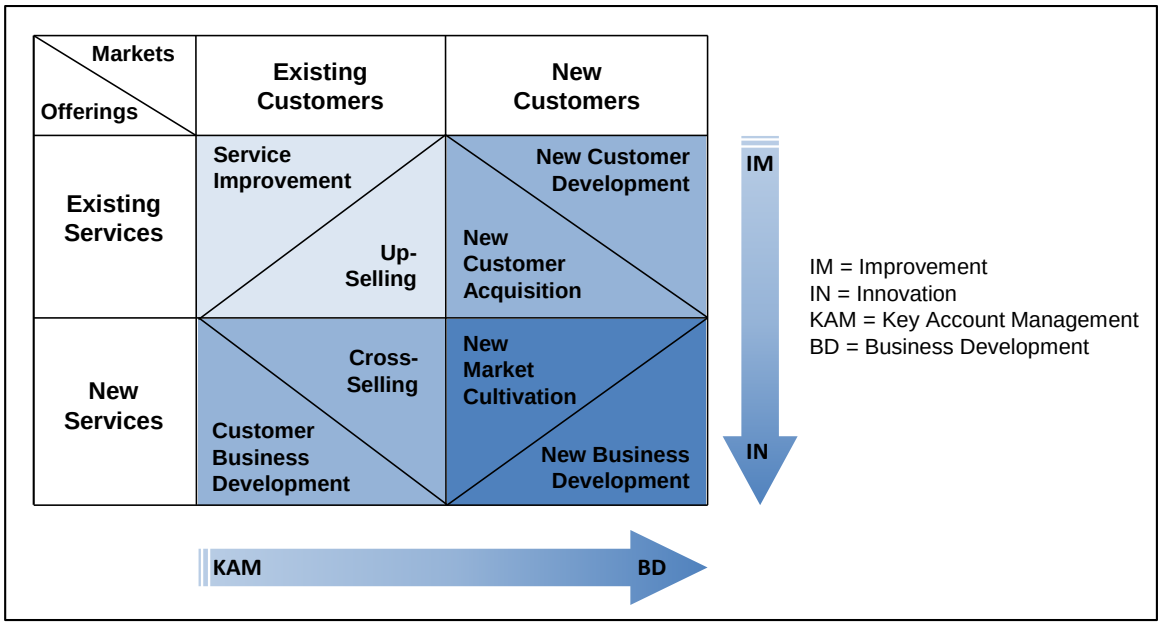

Figure 5.1 First conceptual framework of 3PL business development

The customer-service-matrix differentiates for every field a more strategy-related and a more operative and therefore sales-related approach of BD. The most innovative approach of BD is strategic NBD (new services for new customers). Therefore, a new market has to be cultivated to generate concrete business opportunities. Also, for the other matrix-fields, the operative and strategic BD instruments can be derived. The conceptual framework provides managerial implementations as a complement. 3PL providers can use this matrix for strategic decision making and action planning in BD. Furthermore, they can obtain more transparency about the understanding, types of organization and procedural implementation of BD. In a market characterized, on the one hand, by high potentials in business growth, and, on the other hand, by increasing competition and declining profit margins, these findings are helpful for 3PL providers in order to face their market challenges and win new business more efficiently and effectively.

However, there are some limitations of our study. Firstly, the regional focus is laid on Germany. Therefore, the results are only related to the 3PL services business in this region. Even if the German 3PL industry is one of the most important logistics market segments in Europe, an analysis and comparison of multiple regions has to follow the trend of internationalization and could help to identify best practices (Maloni and Carter, 2006). Secondly, only the providers' perspective of BD is considered in our research. An investigation of the 3PL relationship perspective on development and realization of 3PL services businesses would supplement our results (also suggested by Selviaridis and Spring, 2007). Finally, further qualitative and quantitative research is needed in order to analyze cause-effect relationships between different types and practices of BD and performance.

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APPENDIX

Interview guide

1. What do you understand by business development (BD)?
2. Are you practicing BD in your company's third party logistics (3PL) business?
3. What goals are pursued by BD in your company's 3PL business?
4. How is BD integrated in the company's organization structure?
5. How is BD related to other corporate functions e.g. marketing and sales?
6. Who is responsible for BD in your company's 3PL business?
7. What BD activities are performed in your company's 3PL business?

SECURING INTERNATIONAL BUYER-SUPPLIER RELATIONSHIPS:

The Case of Exporting Firms of the Sunnmøre Region of Norway

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ABSTRACT

Purpose
The purpose of this paper is to provide further insight on the underlying factors that firms engaged in international buyer-supplier relationships should consider in safeguarding their business relationships.

Design/methodology/approach
The paper uses multiple cases of exporting firms within the Sunnmøre region of Norway.

Findings
Firms in the Sunnmøre region of Norway use a variety of governance forms to secure and safeguard international buyer-supplier relationships depending on a variety of factors such as market condition; product type; documentation and payment method; type of customer, and the destination of goods being exported since this impacts on the quality of international buyer-supplier relationships and export performance.

Research limitations/implications
This study involves multiple case studies of firms operating within one industrial region of Norway. Though findings of this study cannot be generalized it may be possible to transfer some general statements across industries and regions.

Practical implications
Institutionally embedded governance forms should take into consideration factors such as the export market condition; product characteristics; documentation requirements and payment methods; type of customer and the destination of exported goods. The choice of governance form(s) in safeguarding international buyer-supplier relationships should be done based on these underlying factors because of the uncertainty/complexity of international trade and the investment of specific assets.

Original/value
The use of multiple case examples elicit the commonality of themes which this paper seek to highlight despite differences in the firms' products, strategies and business models.

Keywords: International buyer-supplier agreements, contracts, trust-based relational contracting, payment methods, governance.

1. INTRODUCTION

Notwithstanding the growing literature on international buyer-seller relationship, limited attention has been given to how exporters secure business relationships with trading partners in overseas countries. International buyer-seller relationships involve complex procedures and documentation in order to ensure goods and services are delivered as per the terms and agreements between contracting parties. For example the use of Incoterms, Incoterms 2010 published by the International Chamber of Commerce (ICC) are intended to reduce or altogether remove uncertainties from different interpretation of rules in different countries. These incoterms are regularly used in international sales agreements and contracts worldwide. Incoterms fundamental function is to allocate costs; risks and responsibility for export and import agreements between the parties involved in international sales transactions. Despite the common use of incoterms in international sales transactions and agreements, international buyer-seller relationships are not without problems. This is because different countries have different legal regimes, business practices, rules and regulations. To reduce countless legal litigations, financial loss and risk, it is essential to ensure efficient trading within international business relationships.

Forming and nurturing sound buyer-seller relationships have often been regarded as the core of international business (Håkansson, 1982; Leonidou, Barnes and Talias, 2006; Leonidou, Palihawadana, Chari and Leonidou, 2011). This is because such relationships set the framework within which buyers and sellers interact, coordinate their activities and exchange resources in the global marketplace (Leonidou et al., 2011). The relationship between foreign partners is influenced by different cultural, economic and environmental factors. In exporter-importer relationships the exporting activities do not only involve economic transactions but also complex behavioural interactions. It is normal to assume that exporting firms as suppliers will safeguard their relationship with business partners in international markets through the use of stringent formal contracts. This is because international buyer-seller relationships can sometimes be very problematic leading to costly legal litigation and subsequent termination of such relationships. Disputes in international sales transactions often arise because the parties did not record their agreements or failed to discuss an issue and to reach an agreement (Johnson and Bade, 2010). The overall research topic is concerned with how firms engaged in international buyer-seller relationships make use of appropriate governance form to safeguard their business relationships when trading and to uncover the influencing factors that impact on the choice of governance mode associated with trading. Hence, the objective of this paper is to provide insight on how firms engaged in international buyer-supplier relationships safeguard their export-import business relationships by the use of an ‘‘appropriate governance mode’’. The research question is stated as: 1) how do firms engaged in international buyer-seller relationships make use of appropriate governance form in international trading to safeguard their business relationships? 2) What are some of the factors that influence the choice of these governance modes in international trading?

2. LITERATURE REVIEW

2.1 Contracting and governance

Transaction cost economies (TCE) is a widely used theory for studying inter-firm relationships. The theory seeks to explain efficient inter-firm governance by its focus on situations where exchange partners make specific investments dedicated to a particular relationship. This results from the need to safeguard investments made by the use of non-market governance against

opportunism. This non-market governance mechanism is called formal contracting (Williamson, 1985). According to Williamson (1998, p. 23), "a key conceptual move for both [new institutional economics and new economics of organization] was to push beyond the theory of the firm as a production function (which is a technological construction) into a theory of the firm as a governance structure (which is an organizational construction)". Transaction cost theory perspectives on the theory of the firm and market organization are partially complementary and partly rival. In that the theory helps in explaining the mechanisms that the theory purports to explain concerning firms and market organization. Generally a variety of such governance structure may be used depending on peculiar characteristics of the relationship.

TCE therefore tries to explain how partners choose from a set of feasible institutional alternative arrangements that offer protection for relationship-specific investments at the lowest total cost. Key characteristics of TCE are: extent to which relationship-specific assets are involved; uncertainty (environmental and/or behavioral); the complexity of the trading arrangement and the frequency with which the transaction occurs. The primary consequence of environmental uncertainty is an adaptation problem due to the difficulty of modifying agreements as a result of changing circumstances while the effect of behavioral uncertainty is the performance evaluation problem that is the difficulty of verifying if compliance with established agreement has occurred (Rindfleisch and Heide, 1997). Formal contracts may serve as a communication tool for reducing perceived transactional uncertainties and/or merely for the existence of a business deal (Roxenhall and Ghauri, 2004). Dyer and Singh (1998) refer to these as a class of agreements enforced by third parties such that TCE perspectives falls primarily within this class. Dispute resolution requires access to third party enforcer, whether it be state or a legitimate organization authority (Gold, 2012).

However, while TCE focuses on formal contracting as the primary mechanism to safeguard specific investments (Williamson, 1991), other researchers suggest a key property of all relationships is the reliance on norms and shared values resulting in relational governance (e.g. Macneil, 1980; Dwyer, Schurr and Oh, 1987). Thus, using TCE perspectives, relationship governance can be described in terms of formal contracting while alternatively relationship governance can also be described in terms of *norms or trust-based mechanisms* termed relational contracting theory. A third option of governance is the ''mixed or hybrid'' where relational contracting complement formal contracting. Relational contracting theory offer alternative mode of governing international buyer-supplier relationships. Pfeffer and Salancik (1978, p.147) define norms as ''…commonly or widely shared sets of behavioral expectations''. Norms are according to this view an expression of business relationship interdependency measurable through e.g. exchange behaviour. Norms may also be considered as ''guidelines for the initial probes that potential exchange partners may make towards each other'' (Scanzoni, 1979, p. 173).

Norms accordingly represent ways to control and potentially develop exchange (Stinchcombe, 1986; Gundlach and Achrol, 1993). The usefulness of formalized contracts diminishes as uncertainty increases and the importance of institutional arrangements then increases. The existence of relational norms in a business relationship is regarded as foundation for harmony (Ouchi, 1980; Ivens, 2006). Relational contracting theory (Macneil, 1980) posits that prior history of a relationship is expected to lead to certain norms; trust and personal relationships that affect the way the relationship between two parties is organized (Macneil, 1980; Buvik and Reve, 2002). Relational contracting theory predicts that as relationships evolve over time relational norms are established (Macneil, 1980; Granovetter, 1985; Bradach and Eccles, 1989). Relationship duration has also been recognized as an important element in relational contract theory (Ring and Van de Ven, 1994). The history of the relationship following its timeline

through its existence and development brings about norms and trust formation. Trust is important in a business relationship when there is risk of mutual dependence as relational trust is derived from repeated interactions over time. Norm as governance structure is developed in international buyer-supplier relationships as result of trust build-up between the contracting parties having dealt with each other over a period of time. Trust reduces uncertainty and the threat of opportunism (Heide and John, 1990; Wathne and Heide, 2004).

2.2 Research model

A typical international buyer-supplier relationship can be governed taking into consideration the need to safeguard investments made by the seller, the buyer or both parties. Taking the perspective of the exporter, uncertainty and/or the complexity of the export market requires the need for safeguarding relationship specific-investments. For example political instability in overseas countries, cumbersome regulatory procedures and rules, unfair competition in the market are some of the factors that can make international business transactions very risky. Cultural differences in terms of norms, values and beliefs and language barriers also pose challenges to doing business in foreign countries. These differences might influence the way business is done in those export markets and hence the choice of governance form. For example, not only does the physical distance between the seller and the buyer's geographic location have influence on the market expansion efforts and the business relationship but also, psychic distance. Figure 2.1 below shows a conceptual framework illustrating the choice between the different governance modes.

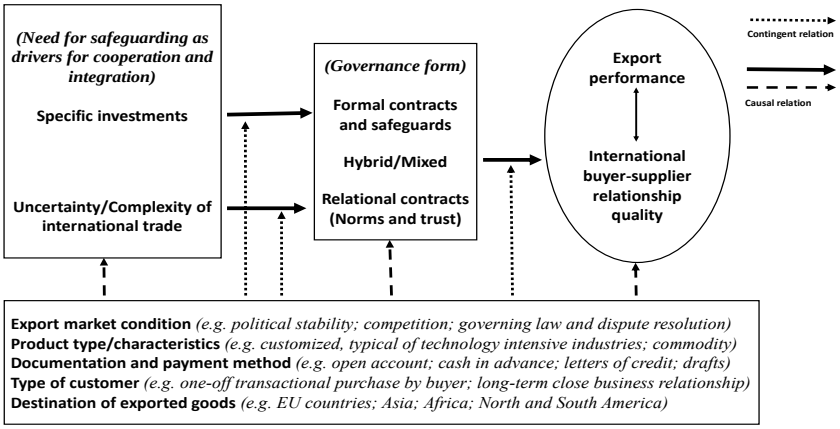

Figure 2.1 Conceptual framework of the choice of governance forms in international buyer-supplier relationships and its underlying factors.

Five factors are accordingly proposed in line with as influencing trading: 1) export market condition, 2) product type/characteristics, 3) documentation and payment method, 4) type of customer, 5) destination of exported goods. The factors involve key features involved in trading within a business relationship associated with international trading as well as its context and wider network environment. The link between relationship specific investment and interfirm governance have been widely studied with few who have paid attention to its underlying considerations (e.g. Ghosh and John, 1999; 2005; Buvik and Reve, 2002; Buvik and Haugland, 2005). Svendsen and Haugland (2006) study of the wood industry in three Nordic countries (Norway, Sweden and Finland) conclude that product differentiation and importer specific investment are two dominant factors explaining the level of exporter specific investment. Export market uncertainty may be associated with high level of formal contracting and low level of cooperative norms. The characteristics of the product (such as customized products) may require more coordination and investment of relationship-specific assets (Svendsen and Haugland, 2006). Distance between importer and exporter has also been found through

quantitative studies to be a strong moderator between relationship effectiveness and adaptation. When the importer feels distant (e.g. geographically, socially, culturally) from the foreign supplier, the effect of adaptation on relationship effectiveness is relatively lower than when there is closeness with the partner (Leonidou et al., 2011). Figure 2.1 therefore provides the basis for analysis of the multiple cases presented in section 4 and subsequent discussions in section 5 of this paper.

3. METHOD

3.1 Multiple case study

This study applies a multiple case study qualitative strategy involving interviews with 5 different companies. Investigation was organized as an individual sub-project with different researchers. Each of these companies was personally interviewed only once. This was an in-depth interview lasting 1-2 hours. In some cases the key informant was supplemented by other informants. Informants also gave some written information as well as those interviews were followed by brief telephone interviews as well as e-mail queries. The interviews took place with informants in five separate cases. These informants represented key positions in their organization such as marketing or purchasing manager, on occasion assisted by their functional employees such as personnel with responsibilities of specific trading regions or functions. Given the explorative nature of this study and the access to the required actual market settings, the case study research strategy was chosen. The case research method is considered by Miles and Huberman (1994) and Yin (2009) as suitable for the following objectives: 1) to answer the research question on ‘‘how?’’ and ‘‘why?’’, 2) researchers cannot manipulate behaviour involved during the research process, and 3) researchers seek a picture of the context the phenomenon is embedded in. Taylor (2005), Fernie and Thorpe (2007) and Lincoln and Guba (1985) stated that this method is appropriate for describing actors, structure and agency relations taking place through social interaction. Case studies were used, in line with Yin (2009), as a means to create focus and order in a complex research setting consisting of multiple, different and interacting heterogeneous resource components. A multiple case approach is chosen since this allows comparison of conceptually similar processes in different settings (Voss et al., 2002). Furthermore, Eisenhardt’s (1989) approach was used to shape the case study research strategy, which involved developing an empirically anchored theoretical understanding of discourse in seafood distribution.

The purpose of the interviews was made explicit to the informants at the outset. Based on the analytical framework, this data is used to create a detailed and rich case description (Lincoln and Guba, 1985) where features of trading were sought evoked from interviews with informants unfamiliar with the applied analytical framework encompassing relational contracting theory. These narrative descriptions are based on the informants’ accounts of their past experiences, or of possible risk-related futures as the primary data (Corsaro and Snehota, 2012). Trading is accordingly studied retrospectively. Interviews lasted on average 1 hour and included observations of on-site activities, namely trading and trading-related operations. Reliability and validity are two important criteria for assessing the procedures and results of qualitative research (Kirk and Miller, 1986; Flick, 2014). Researchers can follow different ways in order to increase the reliability of data and interpretations. The quality of recording and documenting data is central for assessing reliability and succeeding interpretations (Flick, 2014). Since this study used multiple case approach with different researchers collecting data, one way of ensuring reliability of data was the standardization of field notes. ‘‘Standardization of notes increases the reliability of such data if several observers collect the data’’ (Flick, 2014, p.482).

Ensuring reliability of data also involved the training of interviewers and the use of common interview guides. Whilst ensuring validity can also be achieved by involvement of the actors (subjects or groups) in the research process… *communicative validation* (Flick, 2014, p.484). These procedures were followed rigidly to ensure reliability and validity of the study. The various interviews took place in a context of high mutual trust and resembled therefore a conversation with an inter-subjective atmosphere that partly resembled a mutual learning process. The researchers learning about the process the informant had access to, and the informant learning about our concepts and theories driving our research. These interviews were taped and transcribed. Brief additional questions were posed to informants after their interviews when in need of clarification which further added to the study's validity. Although a limited number of transcripts were made based on each interview, these interviews include great detail. These actual circumstances add to the credibility and accuracy and enable a rich and "thick" description of the events through a mutual frame of understanding (see e.g. Eriksson and Kovalainen, 2008; Lincoln and Guba, 1985).

3.2 The Empirical Setting

Global value chain has become a useful concept that helps in the description and analysis of the international and geographical fragmentation of contemporary supply chains (Gereffi and Lee, 2012). Porter (1990) used the term value chain in the description of firm strategies with respect to the management of inter-firm relationships with a focus on competitive advantage. In this study the value chain represents an industrial network of different interlinked companies trading similar-type products. This represents in this study the environment of the studied trading practices. Business relationships are embedded in this network context and trading is carried out in the context of single dyadic business relationships.

First we consider the empirical region this study was carried out in to evoke some regional particularities of the network environment of this study. The Sunnmøre region of Norway is the southernmost district of the Norwegian county of Møre og Romsdal (English: Møre and Romsdal) with its main city called Ålesund (English: Aalesund). Sunnmøre is one of the districts while the other two are: Romsdal and Nordmøre (see Figure 2.2).

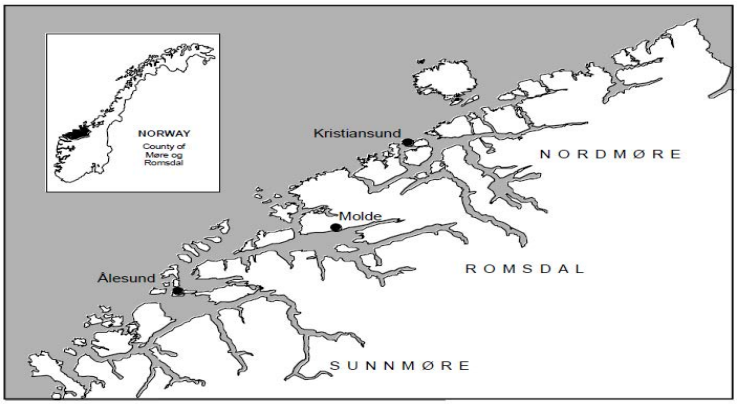

Figure 2.2 The maritime cluster in North West Norway (Source: Halse, 2014)

Ålesund is the administrative center of Ålesund municipality which is approximately 450km north-west of Oslo (Prenkert, Engelseth and Raabe, 2010) with a population of 45,747 as at the third quarter of 2014 (Statistics Norway, 2015). The town consists of a series of small islands on the coast, off which the continental shelf extends with its hundreds of miles of rich fishing grounds and oil reserves. Ålesund dated back to medieval times when the place was first inhabited by people who found the strait between the islands of Aspøya and Nørvøya to be a

good place for fishing and trading. In the 1500s the first merchants came to the natural harbor and the proximity of rich fishing spots off the coast led to the development of Ålesund as a fishing town (Prenkert, 2013). The city is the hub of Norway's networked maritime industry and the center of Norway's fish industry. This network is essentially in nature (Hammervoll, Engelseth and Halse, 2014), with many connections to the global maritime and fish industry. The furniture manufacturing sector is also located slightly inland fjord region, and the maritime (shipbuilding and shipping) is located mostly in the coastal part. Previous studies highlight the maritime industry as the strongest and most dynamic one in Norway (Reve et al., 1992) and the most globally anchored (Reve and Jakobsen, 2001). The Norwegian maritime industry consist of industry sub-units such as research, technology and design, shipbuilding, equipment, shipping, finance and insurance. The cluster also includes firms that export other products related to the maritime sector such as ship design, propulsion systems, deck machinery and equipment for seismic and subsea applications (Halse, 2014, p.90).

The maritime cluster including ancillary industries in the Møre and Romsdal County is predominantly an export industry within the broader global market place. The seafood industry in Norway is export driven, Norwegian seafood companies export to more than 150 countries, with exports reaching 68.8 billion Norwegian kroner at the end of 2014 (Norwegian Seafood Council, 2015). Many markets are subject to globalization, thus the maritime industry, wood and wood products (furniture manufacturing) and the fishing industry in north-west Norway are no exception. Followed by this increased internationalization and globalization some structural changes can be seen within these industries. This calls for cooperating through business relationships with other actors within the network. For example the need to cooperate in the supply chain has focused on securing recurring sales through marketing efforts and coordinating logistical activities (Prenkert et al., 2010). Theoretical and empirical studies suggest that establishing close relationships and partnerships in international markets can be a fruitful strategy to improve export performance while avoiding large scale investments (Cavusgil, 1998; Svendsen and Haugland, 2006). Close business relationships are characterized by the level of specific investments made by the seller and the buyer to the relationship; formal contracting and norms that govern the relationship.

4. CASE PRESENTATION

4.1 Brødrene Sperre

Brødrene Sperre AS is a Norwegian small and medium enterprise (SME) which was established with the main objective to export. Thus, more than 90% of its turnover is from export. The company is a leading supplier of frozen pelagic fish as well as salted and dried fish. The company has a rich family heritage from the 1950s as traditional processors of salted, dried and frozen white (mostly cod) as well as frozen pelagic fish. The company has a state of the art processing facility and logistics center exporting seafood worldwide (Sperrefish, 2015). Brødrene Sperre (BS) inbound logistics consist of receiving fish from fishing boats (frozen or fresh). Pelagic is graded into different sizes, packed into cartons and frozen for storage in the cold stores. Dried salted fish is rather more process intensive. Fish received by BS is mostly frozen. It is defreeze, split in half and salted and moved to cold storage after a couple of weeks of drying. Marketing and sales consists of selling the products to their customers, preferably at a time where it will generate the most profit. BS costumers are mostly importers or supermarket chains, as well as business customers which buy the fish for further processing. BS export fish to most European countries, through important ports like Klaipeda in Lithuania, Szczecin in Poland and Velsen in the Netherlands. In Great Britain BS have a subsidiary distribution

company doing business on its behalf. For customers located in the EU the amount of documentation is less than for the rest of the world, as Norway is part of the European Economic Community (EEC). Export to the EU require three main export documents in the sales process: the commercial invoice, the catch certificate and the shipping document. In addition, a number of optional documents are provided at the customer's requests, e.g. price list, packing lists, quality declarations, and health certificates.

It is recommended that when the seller wants to make regular sales to an importer, the exporter uses written agreement to govern their relationship. BS agreements are based on mutual trust and is not formalized in any way. BS says that with their stable customers they both know how they would like to do business and they agree on the price based on these pre-agreed terms. However, it is a common knowledge that disputes are not uncommon in international sales transactions because the parties did not record their agreement or failed to discuss an issue and reach agreement (Johnson and Bade, 2010). To this day BS says that they have never had a conflict with a customer that they have not been able to settle amicably; this may be why they do not yet see the need for a written agreement between them and their most stable and reliable customers. BS also negotiate the terms and conditions for each sale, except from customers with whom they have close, stable and long-term business relationships. The terms and conditions they agree upon depend on market conditions, for example sometimes it is the buyer's market or the seller's market such that each party may have an upper hand in the negotiation. Disputes arising from breach of contracts are settled using neutral legal jurisdiction such as the court of Stockholm. However BS has managed to settle its disputes amicably without resorting to court actions. BS often uses a letter of credit (L/C) for clients in China, but also sometimes used for European customers. To avoid financial loss and other risk, BS mostly rely on pre-payment from their EU customers. BS customers trust the company it will deliver and are therefore not worried by making payments before goods are supplied.

4.2 VARD

VARD is one of the major global designers and shipbuilders with headquarter located in Norway. The company designs and build specialized vessels used in the offshore oil and gas exploration, production and oil services industries. The company operates with ten strategically located shipbuilding facilities to maintain their reputation as a reliable shipbuilder with a focus on quality and trust. The company has five facilities located in Norway, two in Brazil, two in Romania and one in Vietnam. In 2010 Fincantieri Oil & Gas bought almost 56% percent of the group making it the 4th largest shipbuilding company in the world. The company takes pride in their innovations and the changes they make in the industry by constructing complex, highly advanced and customized offshore and specialized vessels. The main reason customers want to do business with VARD is because of the level of trust VARD builds with their customers. In all projects they strive to have an open and trustworthy relationship with their customers to find suitable and satisfactory solutions. Everything the firm stands for can be summarized in one sentence: "We build our company on trust!" (Vard, 2015).

We distinguish between ongoing long-term and isolated purchase transaction. Isolated purchase transaction involves one-off transaction with minimal close relationships. This transaction includes higher risk for the seller because the buyer may be new requiring creditworthiness checks. VARD sells expensive equipment and vessels and thus prefer secured ongoing purchase transactions. This kind of transaction requires more formal documentation and more consideration into the design of the sales agreement, because VARD focus on repeated purchase through trust-based relationship with their customers. In spite of the fact that 99 % of VARD's export is within the company between its subsidiaries in other countries, there are challenges

due to different regulations in the importing countries. Foreign law is one of the key issue for export compliance.

The purchasers of this type of high cost vessels appreciate quality and loyalty. Most of VARD's customers are located within the Møre maritime cluster, and have repeatedly purchased ships from them. Since the product is a ship and these specialised offshore support vessels are used by a global industry, the market is global in product use and more regional in relation to trading the vessels. VARD is a strong competitor in the international offshore vessel market because of their innovativeness. This makes their products more attractive for the customers because it offers them better solutions and possibilities. This differentiation strategy gives VARD a competitive advantage. Trust is also an important issue for VARD, hence by building relationships based on trust with their customers this translate into increase repeated orders/purchases. To avoid problems with export, VARD follows a number of routines. They consider many of the "import provisions in international sales agreement", in addition to commission, pricing, shipment, warranties and the relationship of the parties when they use agents. They develop their products together with their customers so that the customers' needs can be fulfilled. This involves decisions from design, size and color to the boats' high-tech technology in order to fulfil the customers' needs. All trades are contract-driven, where both the customer and the seller have to abide by the contract agreement. However, due to the prolonged time duration from contracting to completion which may last up to two years, ships contracted may be traded prior to completion as well as that payment is withheld until the ship is delivered. To ensure construction, payment is guaranteed through financial institutions, a necessary part of contracting ships.

4.3 Stokke

Stokke AS is a Norwegian company from Møre & Romsdal founded in 1932. The company has offices in Oslo and Aalesund. The company has no official main office because its philosophy is to appear international with equal emphasis in its operation in all the countries it has presence. The two offices in Oslo and Aalesund has main responsibility for product development, IT, finance, logistics and supply chain management and marketing. In 1972 Stokke AS created the iconic and innovative "TrippTrapp-chair" for children. Since 2006 the company has focused on children equipment, such as highchairs, strollers, and furniture for the nursery. In 2012 Stokke AS had a turnover of over 1 billion Norwegian kroner. Stokke AS has a strong focus on brand where quality and innovative thinking is essential. At the end of 2013 Stokke AS was sold to the Korean company NXMH, an investment company based in Belgium and wholly owned by NXC in South Korea. The Stokke collection of products is distributed worldwide in over fifty countries. Thus, with an export share of 98%, Stokke AS is a typical export company (Stokke, 2015). All the products developed, produced and marketed are considered ''Norwegian'' as the country of origin, although all production is outsourced. Stokke AS manufactures its products in Eastern Europe and China with three main distribution centres in the Netherlands, USA and China to serve its customers in Europe, Asia and America. Stokke AS has offices in almost every country they are available in. Where Stokke AS do not have offices, they have distributors and agents that purchase products and handle all the import procedures.

The company uses formal agreement with all its suppliers including confidentiality agreements to avoid copyright infringement and to protect its patents. Stokke AS is very formal regarding all of their suppliers, as well as the major logistics contracts. For international sales agreements certain minimum requirements such as volume, products types, and in store display by distributors are negotiated between Stokke AS and the importer. Stokke AS use of terms of payment depends both on who the customer is and where they are located. In Europe it is most

common using invoice with 30 days credit. In more unknown markets where Stokke does not have offices or good knowledge about the buyer, for example new customers, it is common using prepayments. Stokke AS used prepayment in most of their international sales transactions especially in Asia before they established own offices in the Asian market. Another option they have with new customers are the use of letters of credit. However, this is rare because Stokke AS considers it as a ‘‘bothersome way of working’’ and require that the order need to be quite substantial to be considered a profitable business. Stokke as the focal company has a network involving its suppliers, transport companies, distributors, insurance companies, agents and custom brokers and financial institutions. Trust and relationship building is an important strategy that enable Stokke AS to efficiently undertake its exporting activities.

4.4 Jangaard Export

Jangaard Export AS which was founded in 1931 is located in Aalesund and is one of Norway’s leading producers and exporters of dried salted fish (often called bacalao). Jangaard Export (JE) focuses on high quality products and the development of a strong brand in its export markets. JE main export markets are Portugal, Brazil and Africa. For example, JE has been in the African market since 1960 and has very good market knowledge and high market share of the African export market consisting of countries such as the Republic of Congo, Tunisia, South Africa and Angola. In Europe JE can be found in Portugal, Spain, Greece and France. In South America, JE exports to Brazil, Dominican Republic, Venezuela, Mexico and Argentina. One of the most important consideration in exporting has to do with ‘‘payment’’. Trust and close business relationships help avert some of the fears with international transactions. For example Greek importers of JE who had long established business relationships with JE but had problem with international insurance companies during the financial crisis (beginning from 2009) and were refused insurance coverage, had some of these business problems amicably solved through negotiation and goodwill.

JE has presence in all its major export markets but uses agents in smaller and more risky markets. JE uses formal sales agreements to deal with all its customers but additionally use oral agreements with close and trusted business partners. JE hardly experience disputes despite the use of these informal approaches in dealing with some of its customers. JE use of payment terms differ depending on geographical area and customers. While customers with long established business relationships with JE may get longer terms of payment based on history of previous sales transaction and trust others may have shorter payment duration terms of credit. Customers in Europe who have long established relationships might have 30 days credit. Close relationship with some customers such as supermarkets in some European countries are evidenced by the long history of dealing with JE. Some of these supermarkets are connected by electronic data interchange (EDI) systems where information flow is real-time. This obviously require investments in specific assets by both JE and the supermarket chain in those countries.

Customers in faraway markets with unstable political systems require payment upfront or use of letters of credit. Africa as a whole considered as an export market destination is JE’s second biggest market and considered as less problematic in contrast to Brazil where the legal requirements and the business climate is considered ‘‘problematic’’. Thus the differences in these various export markets require different strategies for JE to implement in dealing with importers, agents and distributors. The European market is considered as one of the most important ones due to its proximity and market conditions. European supermarket chains are very important customers for JE though dealing with such chains have some challenges. A sales representative has this to say: *“The only solution is to become so large that they need you. If you are small, you are insignificant to them, and have more difficulties dealing with them”.* Hence, the political stability of the market, its size, customer base, macroeconomic conditions,

market share and branding are important factors to consider in the internationalization through exporting especially for the seafood market.

4.5 Mørenot Group

The Mørenot Group consist of companies with leading positions in international markets as suppliers to customers in fisheries, aquaculture and the marine seismic. Mørenot Fishery operates in the nets and trawls segment; Mørenot Aquaculture produces netting, fish farming nets and mooring to the aquaculture industry with facilities in Norway and abroad; Mørenot Dyrkon is a leading supplier of swivel and hook for marine, coastal and deep fishing. Mørenot is a well-established supplier of equipment to the global marine seismic industry (Mørenot, 2015). Mørenot Offshore AS (MNO) will be the focus of this case presentation. MNO is located within the center of the North-Sea oil enclave and part of the world's leading maritime cluster of Møre and Romsdal. Its main international markets are Europe, China, Canada and Turkey. MNO produces high performance ropes, strong and flexible ropes for all seismic activities. Mørenot also manufactures hardware of high quality, efficiency, safety and reliability. The company has reputation among its customers as producers of high quality products. Thus, over the last thirty years, MNO's experience and metallurgical skills have led to continuous improvement in its products to enhance efficiency, safety and reliability of its products for seismic operations.

MNO is can be classified as a small and medium enterprise operating in a niche market. MNO's competitiveness lies in providing innovative solutions and responding to customers' needs efficiently. MNO's uses agents in some markets. For example, the Chinese market is handled by an agent whose knowledge of the peculiar market conditions, language and business culture handles all documentation and import procedures in China. MNO prefers close long term business relationship with its customers. MNO also prefers to have face-to-face contacts with customers to negotiate business contracts. This helps to establish close collaborative business relationships especially in an industry that places high premium on quality, safety and reliability in the provision of solutions to customers. MNO internationalization also involves the use of direct export to its customers without using agents. The use of formal contracting are therefore typical in this industry, however because of the long-term relationship established with some of these customers the use of norms and trust plays a greater role in these international buyer-supplier relationships. Payments methods used by MNO depend on the type of customer. For example open account is used for some customers with credit up to 60 days. MNO has close and trustworthy relationships with such customers it extend credit to.

5. ANALYSIS AND DISCUSSION

Analysis and discussion includes the following themes: 1) export market condition, 2) product type/characteristics, 3) documentation and payment method, 4) type of customer, 5) destination of exported goods. Export markets vary to some degree. Most of the companies except for Stokke and Mørenot Group, operate on relatively limited parts of the global marketplace. Sperre sells its pelagic seafood products primarily in Eastern Europe, and Jangaard Export sells its bacalao products to predominately Latin-culture countries and Greece. Food is a highly culturally-embedded type of goods, and the distinction between the export markets of Brødrene Sperre and Jangaard Export is explained by this factor. VARD finds most of its customers in Norway due to long established business relationships in a marketplace that started to exist coinciding with the development of the petroleum industry in Norway in the late 1960s. The offshore support vessels are complex and laden with high technology components that undergo rapid technological change. Location proximity in trading mitigates risk in this case. Stokke

and Mørenot Group are both true global actors. Mørenot group is limited to nations that have a marine industry, and Stokke is preferably sold on markets that appreciate their relatively high-prices slow-moving consumer goods. The cases cover a broad range of products. Pelagic seafood sold by Brødrene Sperre is a low value-high volume industrially processed product traded on a commodity market. This product is similar to the bacalao product traded by Jangaard. VARD carries out shipbuilding, pricing a large and expensive product over a prolonged time-period. Since VARD's shipyards in Norway are relatively small, each shipyard is focused on very few shipbuilding projects at the same time. Mørenot produces industrial equipment used in the seafood industry. These are small volume technically advanced products.

Documentation and payment is in all five cases relatively formalized at core. VARD's documentation needs are quite different from the other cases based on the primarily product characteristics discussed above. Documentation in this case is complex and carried out over a prolonged timeline in comparison with the other cases. This documentation process is, fundamentally similar to the other cases. They are all embedded in highly institutionalized contexts. Norms and rules of documentation have long been established and are not subject to variation. It is interesting to note that documentation in some firms vary depending on primarily market type. This is associated with levels of trust established within business relationships, such that prepayment is demanded in regional markets normally associated in general with a lower level of trust. This is especially the case in Brødrene Sperre and Mørenot Group. Brødrene Sperre sells most of its goods to Eastern Europe, a region associated with high risk, and therefore demands prepayment on all these exports. This indicates that even though trust may develop in individual business relationships, the culture of these relationships does not easily change overall norms of trade for an existent marketplace.

The type of customer is associated with its business relationship. Firstly, we therefore consider company characteristics. These companies are also extremely varied regarding their different technical, managerial and size characteristics. All companies except for Stokke are involved in production. Stokke has outsourced this function. The companies are similar in that they are all involved in physical distribution. All companies also are involved in export as an important feature of their business. VARD is also an exporter since ships, even though purchased by a Norwegian ship-owner, is classified as export since ships in the offshore petroleum industry are always used on a global market, and the Norwegian oilfields are also considered as international. The companies are therefore all well established and highly competent operators on the global market scene. Customers are necessary complementary in function, meaning trading is determined by fulfilling supply network actor needs through transfer of product ownership thereby directing logistical flows. The case illustrates how customer characteristics is in part a function of this logic as well as a function of the overall industry characteristics regarding technology, product characteristics and networking features including competition.

The markets these companies operate on also vary greatly. Jangaard Export and Brødrene Sperre both operate on a global commodity market where price fluctuates out of the bounds of the individual exporter. Stokke produces branded products, and thereby differentiated child-related consumer products targeted at upmarket segments on a global marketplace. VARD sells its ships in a highly specialized industrial marketplace, which again is dependent on the commodity market associated with petroleum production and pricing. In the case of VARD branding is of more limited importance on the marketplace. Mørenot Group also sells goods, and its branding is important since they compete with similar companies offering similar products on the global marketplace.

Several underlying factors necessitate the choice of governance mode in international buyer-supplier relationships. The conditions of the export market, the type of product and its characteristics, documentation and payment methods, customer type and the destination of the

goods have influence on decision concerning investment of relationship specific assets by the parties. These factors have been briefly discussed here and unveil understanding how trading, although formalized contracting is core to trading, this formalization is embedded in line with relational contracting theory, in institutionalized economic behavior. Institutionalization is associated with uncertainties in the market with respect to the level of competition, level of political stability and the legal environment dictates not only investment decisions but how relationships are governed. Product characteristics such as highly customized products in technologically intensive industries require formal coordination and cooperative norms between partners. Cumbersome documentation in some importing countries impact on the way firms internationalize into those markets, in most situation requiring the use of agents who have better knowledge of the business environment. Geographic and cultural distance between importers and exporter plays very import role in adaptations in international trade with its consequent impact on export performance. Actors perceive risk and formal contracting simply cannot handle these uncertainties.

The five brief cases altogether reveal accordingly how developed business relationships in fact represent a resource. This underpins the view of Håkansson and Snehota (1995) that business relationships are a resource in itself that may be analyzed as separate from the firm. The cases illustrate how export market condition, product type/characteristics, documentation and payment method, type of customer, destination of exported goods are factors that in different ways are not primarily formalized facts, but factors associated with institutionalized behavior. These factors also encompass factors wider than the business relationship; the industrial network and its wider environment. Institutionalized trading behavior emerges in business relationships as operational solutions, embedded in a wider culture of the company embedded in its network. This is in line with Håkansson and Persson (2004), that managing sets of inbound and outbound logistics flows, these flows necessarily will impact on each other through supply chain management. Knowledge of trading is accordingly proposed view as embedded in the totality of the industrial network. In this network formalized contracts cannot encompass all the detail associated with these factors as well as risk associated with them. Formal contracts are a component of institutionalized trading.

6. CONCLUSIONS

In relation to supply chain management and logistics, this case study shows how relational contracting theory, with its focus on detecting institutionalized exchange behavior is a realm of analysis in the supply chain, how contracting as institutionalized behavior also includes logistics considerations, and these considerations are not isolated from other considerations such as marketing, sales, purchasing and payment. This is in line with the view of supply chain management encompassing all types of business process (Lambert et al., 1998). Considering the explorative nature of this study by use of multiple cases of firms operating in different markets with different products but located in the same industrial networked cluster, our findings suggest that export market condition; the characteristics of the product being traded; documentation and payment methods are important considerations for export oriented firms. The type of customer segments and the destination of exported goods have important implications for export management decision making. The structuring of international business relationships for increased export performance should not be done in isolation. In as much as the uncertainties of trade and investment of specific assets dictate the choice of governance form, the key underlying factors need to be considered. With regard to theoretical implication these finding suggest that transaction cost economics can benefit from taking strategic considerations more explicitly into account (Svendsen and Haugland, 2006). Formal

contracting and the use of relational norms are complementary governance mechanisms as supported by previous research (e.g. Cannon, Achrol and Gundlach, 2000; Poppo and Zenger, 2002; Arranz and Arroyabe, 2012). Thus attempt to bridge the transaction cost economies with relational contracting theory provides numerous opportunities for researchers to close the gap in the literature and to increase our knowledge. The use of case study approach involving interviews of key informants of different firms provide very ‘‘rich’’ insight into the problem understudy. However, the findings of this study have limitations. Though it may be possible to transfer some general statements from this study across industries and regions, case study findings cannot normally be generalized. Further research involving other industry clusters involved in exporting can help unearth the untapped knowledge embedded in these clusters and give a better understanding of how international buyer-supplier business relationships are governed. The use of quantitative research method such as survey involving several key informants from either sides or one side of the export-import dyad can help establish some of the associations between the factors that have been identified in this study.

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OPTIMAL ORDER QUANTITIES FOR A FAMILY OF ITEMS UNDER CAPITAL RESTRICTION AND STOCK-OUT COSTS

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Abstract

Purpose: Finding closed formulas for economic order quantities for a family of items under restriction on capital in the cyclic inventory under different service oncepts and stock-out costs.

Methods: The objective is achieved using calculus.

Findings: Closed formulas are found for both the P1 and P2 (fill rate) service concept.

Practical applications: The results could help to monitor inventories in a better way in cases where capital is a scarce resource.

Social applications: Not relevant

Original value: We offer new formulas that have not been published before that could be helpful for management of inventories.

Research limitation: The capital restriction is limited to the cyclic inventories and not to the safety stocks. Further research could be extended to also include these and other restrictions like coordinated replenishment for a family of items.

Key words: Inventory theory, multiple items, closed formulas, different service concepts, restriction on capital.

1. INTRODUCTION AND LITTERATURE REVIEW

Inventory theory has been studied in an academic way for more than 100 years and a huge number of text books and articles have been published over the years. For good and deep overview Silver et al (1998) is recommended, but also Axsäter (2006), Zipkin (2000) and Nahmias (2001) contain the main bulk of classical inventory theory. In inventory theory one usually tries to balance four different cost elements. The cost elements will be order cost, cyclic inventory holding cost, cost of safety stock, and stock out cost. The latter cost will depend on the chosen stock out situation or more specifically, whether the cost of the stock out is per stock out situation, that is a given amount of money in a certain currency like an ordering cost, here after denoted P1, or a cost per unit not delivered directly from shelf like an inventory holding cost, that is a fill rate or P2 service concept. A common set of assumption in this context is that demand rate is fairly level, but with a certain variation during lead time that can be described by a probability function like the

normal distribution. The price per unit of the stored commodity is the same independent of the ordered quantity, that is, no discount is offered. The commodity is always available in the market. Finally, different commodities can be treated independently of each other, which means, they do not share any common resources like capital, number of orders per time period, space in the warehouse or other potential common resources.

During the last decades many of the classical situations have been extended with added restrictions like coordinated replenishments, restriction on space or capital, different discounts strategies either for single items or for families of item with or without added restriction on capital. Many of these extensions can be found in the four comprehensive text books mentioned above. These books show that the most common approach to inventory theory is cost minimization. However, one may also consider maximizing the return on investment (ROI). In this case one wants to maximize the relative profit obtained compared to the investments made in the inventory and in the firm in general like equipment, vehicles, buildings etc. A fairly extensive treatment of some aspects of this approach can be found in Halskau and Thorstenson (1998). Gribkovskaia et al (2012) specializing the situation in the previous article to a family of items under restriction on capital given that the firm has no investments done apart for what is kept in the cyclic inventory. Sete (2013) treats the special situation with planned stock outs for a family of items under restriction on capital tied up in the cyclic inventory obtaining analytical formulas for the optimal order quantities. Pasandideh et al. (2011) treats a multi-commodity situation with multiple restrictions and offer an algorithm for obtaining economic order quantities. Chang et al (2006) treat a single item multi-supplier system with variable lead-time, price-quantity discount, and resource constraint. Haksever and Moussourakis (2008) determining order quantities in multi-product inventory systems subject to multiple constraints and incremental discounts. However, in most of the literature that treats situations with multiple-products with some added restriction; one does not include stochastic elements into the calculations. This is done in the present paper.

In this paper we will relax the assumption that the items do **not** share a common resource and assume that for a family of n different items there will be a restriction on the average capital tied up in the **cyclic** inventory. Optimal order quantities will be offered for both the P1 and fill rate (P2) service concepts.

The rest of this paper is organized as follows: In section 2 we review the classical cases for the two service concepts P1 and P2 (fill rate). In section 3 we extend the results of section 2 to a family of items ordered under the restriction of an average capital tied up in the cyclic inventory for both service concepts. In section 4 we give a small illustrative example showing the differences between the solution in section 2 and 3 and discuss the consequences of the restriction on capital compared to the unrestricted case. In section 5 we sum up the main conclusions and indicate some paths for further research. For convenience, all formal proofs are given in the appendices.

2. THE SINGLE ITEM CASES

In order to treat these cases we will use the following notation. A will denote the order cost incurred by placing an order by a supplier. v will denote the unit purchasing value for the item, r the inventory holding cost in percentage of the unit value, and d the demand. Hence the

inventory holding cost per unit will be $h = vr$. Assuming a certain variation in the lead-time demand we let σ denote the standard deviation for this time period and z the safety factor. Hence, the cost of the safety stock will be $SS = z\sigma vr$. Further, we will assume that the demand during lead-time is normally distributed and we will denote the cumulative distribution as $p_{u<}(z)$. This means that the probability of having a stock out situation will be $p_{u\geq}(z) = 1 - p_{u<}(z)$. The number of units short for a given standard deviation z is denoted $\sigma G_u(z)$. We will assume a continuous review system with a fixed order quantity. The stock-out costs will depend on the service concept, P1 or fill rate and will be defined below in section 2.1 and 2.2 respectively. The fixed order size will be denoted by Q_{UR1} in the P1 case and Q_{UR2} in the P2, fill rate case. It will be convenient from time to time to use the traditional Harris-Wilson formula:

$$(1) \qquad Q_{HW} = \sqrt{\frac{2Ad}{vr}}$$

2.1 The single item case with P1 service concept.

In a situation with stochastic demand it will always be a certain probability that a stock-out situation may occur. A stock-out situation will always incur some costs in one way or another. In the P1 case we just consider the situation as such not asking how big or serious the stock-out is. The stock-out cost will then be a certain amount of money one has to pay – directly or indirectly – to render the situation in one way or another. Hence, the stock-out cost in this case is like an order cost, if it occurs, you have to pay some money. We will denote the stock-out cost for the P1 case by B_1. Hence, the objective function will be given in (2):

$$(2) \qquad TC_{UR1}(Q_{UR1}, z) = \frac{d}{Q_{UR1}} A + \frac{1}{2} Q_{UR1} vr + z\sigma vr + \frac{d}{Q_{UR1}} B_1 p_{u\geq}(z)$$

where the last term denotes the stock-out costs. Following Silver et al (1998) the optimal order size and the corresponding safety factor can be found using the two formulas (3) and (4) iteratively. A formal proof is given in the appendix.

$$(3) \qquad Q_{UR1} = Q_{HW} \sqrt{1 + \frac{B_1}{A} p_{u\geq}(z)}$$

$$(4) \qquad z = \sqrt{2 \ln \frac{dB_1}{\sqrt{2\pi} Q_{UR1} \sigma vr}}$$

Note that (3) shows that the optimal order quantity in this case always is equal to or larger than the classical Harris-Wilson order quantity. The optimal pair of the order size and the safety factor can be found be a straightforward iteration process using (3) and (4) starting from (4) using the Harris-Wilson quantity as the order size.

2.2 **The single item case with fill rate (P2) service concept**

In the fill rate case the objective function becomes

$$(5) \qquad TC_{UR2}(Q_{UR2}, z) = \frac{d}{Q_{UR2}} A + \frac{1}{2} Q_{UR2} vr + z\sigma vr + \frac{d}{Q_{UR2}} B_2 v\sigma G_u(z)$$

where the last term denotes the stock-out costs. Here $\sigma G_u(z)$ denotes the number of units short during the lead-time, given a normal distribution. The stock-out costs B_2 is a certain percentage of the unit value *v*. Again following Silver et al (1998) the optimal order size and the corresponding safety factor can be found using the two formulas (6) and (7) iteratively. A formal proof is given in the appendix.

$$(6) \qquad Q_{UR2} = Q_{HW} \sqrt{1 + \frac{B_2}{A} v\sigma G_u(z)}$$

$$(7) \qquad p_{u\geq}(z) = \frac{Q_{UR2} r}{dB_2}$$

Note that (6) shows that the optimal order quantity in this case always is equal to or larger the classical Harris-Wilson order quantity. The optimal pair of the order size and the safety factor can be found by a straightforward iteration process using (6) and (7) starting from (7) using the Harris-Wilson quantity as the order size.

3. THE MULTIPLE ITEMS CASES

In this section we will extend the results in section 2 to a family of *n* items denoted *i = 1,2,…,n.* All the parameters will be denoted according to the notation in section 2, but with an added subscript *i.* In addition we introduce a new parameter, the average capital tied up in the **cyclic** inventory for this family denoted *C.* We **disregard** the capital tied up in the safety stock. Hence, the optimal pairs found in section 2 may not be valid any more if the average value of the items kept in the inventory exceeds *C.* Given a family of items we calculate the optimal order quantities and the corresponding safety factors according to the formulas in section 2. Then we calculate the average capital tied up in the cyclic inventory based on these optimal order quantities. If this amount of money is equal to or less than the capital *C,* we have solved the problem for the family under consideration and no changes have to be done. On the other hand, if the calculated capital is strictly larger than the restriction on the capital, the order quantities and the corresponding safety factors have to be adjusted. In such a case we end up with a Lagrangian mathematical model. The two cases under consideration – the P1 service situation and the P2 (fill rate situation) – are treated in 3.1 and 3.2 respectively.

3.1 The multiple items case for the P1 service concept.

In this case we will have the following mathematical model:

$$(8) \qquad TC_{P1}((Q_{R1})_i, z_i) = \sum_{i=1}^{n} \frac{d_i}{(Q_{R1})_i} A_i + \frac{1}{2}(Q_{R1})_i v_i r_i + z_i \sigma_i v_i r_i + \frac{d_i}{(Q_{R1})_i} B_{1,i} p_{u\geq}(z)$$

Subject to

$$(9) \qquad \frac{1}{2}\sum_{i=1}^{n}(Q_{R1})_i v_i = C$$

where $(Q_{R1})_i$ denotes the order size in the restricted case for item *i*. From the model above we formulate the Lagrangian function in (10), λ being the Lagrangian multiplier.

$$(10)\ LF_{P1}((Q_{R1})_i, z_i, \lambda) = \sum_{i=1}^{n} \frac{d_i}{(Q_{R1})_i} A_i + \frac{1}{2}(Q_{R1})_i v_i r + z_i \sigma_i v_i r + \frac{d_i}{(Q_{R1})_i} B_{1,i} p_{u\geq}(z) + \lambda\left(\frac{1}{2}\sum_{i=1}^{n}(Q_{R1})_i v_i - C\right)$$

Taking the partial derivatives with respect to the different variables, we get the following three formulas for the restricted optimal order quantities, the safety factors, and the Lagrangian multiplier. We have assumed that all items have the same inventory holding cost *r* in percentage. Formal proofs can be found in the appendix.

$$(11) \qquad (Q_{R1})_i = \frac{1}{\sqrt{r+\lambda}}\sqrt{\frac{2d_i(A_i + B_{1i}p_{u\geq}(z))}{v_i}} = \sqrt{\frac{r}{r+\lambda}}(Q_{HW})_i\sqrt{1+\frac{B_{1i}}{A_i}p_{u\geq}(z)} = \sqrt{\frac{r}{r+\lambda}}(Q_{UR1})_i$$

$$(12) \qquad z_i = \sqrt{2\ln\frac{d_i B_{1i}}{\sqrt{2\pi}(Q_{R1})_i \sigma_i v_i r}}$$

$$(13) \qquad \lambda = \frac{r}{4C^2}\left(\sum_{i=1}^{n}\sqrt{2d_i(A_i + B_{1i}p_{u\geq}(z))v_i}\right)^2 - r = \left(\left(\frac{\sum_{i=!}^{n}(Q_{UR1})_i v_i}{2C}\right)^2 - 1\right)r = \left(\left(\frac{C_{UR1}}{C}\right)^2 - 1\right)r$$

Combining the three formulas (11) – (13) we can, in principle, now find the optimal pairs and the cost of capital λ for all the items in the family by performing an iteration process for each of them. We also observe that the cost of capital will increase if the capital restriction *C* is reduced, which is to be expected. However, combining (11) and (13) gives the simpler solution shown in (14).

$$(14) \qquad (Q_{R1})_i = \frac{C}{C_{UR1}}(Q_{UR1})_i$$

where C_{UR1} is the average capital tied up in the inventory for the family in the unrestricted case. Hence, it is not necessary to repeat the iteration process. We just find the optimal order sizes in

the unrestricted case, calculate the capital tied up in the inventory and reduce the order sizes with the fraction $C : C_{UR1}$. This fraction is always less than one.

3.2 The multiple items case for the P2 service concept.

In this case we will have the following mathematical model when assuming the same inventory holding cost in percentage for the whole family:

$$(15) \qquad TC_{P2}((Q_{R2})_i, z_i) = \sum_{i=1}^{n} \frac{d_i}{(Q_{R2})_i} A_i + \frac{1}{2}(Q_{R2})_i v_i r + z_i \sigma_i v_i r + \frac{d_i}{(Q_{R2})_i} B_{2i} v_i \sigma_i G_u(z_i)$$

Subject to

$$(16) \qquad \frac{1}{2}\sum_{i=1}^{n}(Q_{R2})_i v_i = C$$

From the above mathematical model we get the following Lagrangian function:

$$(17)\ LC_{P2}((Q_{R2})_i, z_i, \mu) = \sum_{i=1}^{n} \frac{d_i}{(Q_{R2})_i} A_i + \frac{1}{2}(Q_{R2})_i v_i r + z_i \sigma_i v_i r + \frac{d_i}{(Q_{R2})_i} B_{2i} v_i \sigma_i G_u(z_i) + \mu\left(\frac{1}{2}\sum_{i=1}^{n}(Q_{R2})_i v_i - C\right)$$

Solving (17) to optimality we get the following results. Formal proofs are given in the appendix.

$$(18) \qquad (Q_{R2})_i = \sqrt{\frac{r}{r+\mu}}(Q_{HW})_i \sqrt{1 + \frac{B_{2i}}{A_i} v_i \sigma_i G_u(z_i)} = \sqrt{\frac{r}{r+\mu}}(Q_{UR2})_i$$

$$(19) \qquad p_{u\geq}(z_i) = \frac{(Q_{R2})_i r}{d_i B_{2i}}$$

$$(20) \qquad \mu = \frac{r\left(\sum_{i=1}^{n}(Q_{UR2})_i v_i\right)^2}{4C^2} - r = \left(\left(\frac{\sum_{i=1}^{n}(Q_{UR2})_i v_i}{2C}\right)^2 - 1\right) r = \left(\left(\frac{C_{UR2}}{C}\right)^2 - 1\right) r$$

where C_{UR2} is the average capital tied up in the inventory for the family in the unrestricted case.

Combining the three formulas (18) – (20) we can, in principle, now find the optimal pairs and the cost of capital μ for all the items in the family by performing an iteration process for each of them. We also observe that the cost of capital will increase if the capital restriction C is reduced, which is to be expected. However, combining (18) and (20) gives the simpler solution shown in (21).

(21) $$(Q_{R2})_i = \frac{C}{C_{UR2}}(Q_{UR2})_i$$

Hence, it is not necessary to repeat the iteration process. We just find the optimal order sizes in the unrestricted case, calculate the capital tied up in the inventory and reduce the order sizes with the fraction $C : C_{UR2}$. This fraction is always less than one.

4. EXAMPLES

In this section we give examples for the two situations described in section 3 based on data for a small family of 4 items. The data for this family is given in table 4.1 together with the optimal order quantities for the basic, classical Harris – Wilson order sizes. We have assumed the same interest rate as far as the inventory holding costs are concerned and also the same order cost for all the members of the family. These are $r = 20\%$ and $A = 600$ (money units of some sort), respectively.

Table 4.1. Basic data for the examples and the optimal Harris – Wilson order sizes.

Item number	Unit value v	Annual demand d	Stock-out costs B_1	Standard deviation σ	Harris – Wilson Q_{HW}
1	1000	2500	5000	25	122
2	2000	2000	7500	20	77
3	3000	1500	10000	20	55
4	5000	1000	15000	15	35

We start with the P1 situation where the stock-out costs for each of the items also are given

Based on the data in table 4.1 and using formulas (3) and (4), we obtain the optimal order sizes and the relevant cost elements for the unrestricted case for each of the individual items in table 4.2.

Table 4.2. Optimal order sizes and associated cost elements for the four items in the unrestricted case with P1 service concept

Item	Q_{UR1}	Order costs	Cyclic inventory holding costs	Service level P1/z	Cost of safety stock	Stock-out costs	Logistical costs	Average capital in cyclic inventory
1	133	11278	13300	2.01	10050	2088	36716	66500
2	83	14458	16600	2.10	16800	3228	51086	83000
3	64	14063	19200	2.03	24360	4964	62587	96000
4	42	14286	21000	2.12	31800	6071	73157	105000
Sum	-	54085	70100	-	83010	16351	223546	350500

From table 4.2 we see that the total logistical costs for this family are 223546 and that the average capital tied up in the cyclic inventory is 350500. An example of how to calculate the optimal pair, that is, the optimal order quantity and the service level, can be found in the appendix. We also note that the service levels (P1) are pretty high and around 98% for all the four items. The stock-out costs are substantially smaller than the cost of keeping a safety stock. The order sizes are larger than the Harris-Wilson quantities as shown theoretically. It is also worth to notice that the capital tied up in the safety stock is roughly at the same level as the average capital tied up in the cyclic inventory

Now assume that we want to reduce this capital with 100000, that is, C=250500. In order to obtain this, the order sizes must be reduced. Using (14), the ratio 250500 : 350500 = 0.715, the optimal order sizes from table 2 we get the optimal order sizes for the restricted case and the associated costs and service levels in table 4.3.

Table 4.3. Optimal order sizes and associated cost elements for the four items in the restricted case with P1 service concept and average capital restricted to C = 250500

Item	Q_{R1}	Order costs	Cyclic inventory holding costs	Service level P1/z	Cost of safety stock	Stock-out costs	Logistical costs	Average capital in cyclic inventory
1	95	15789	9500	2.17	10843	1974	38106	47500

2	59	20339	11800	2.25	18032	3107	53278	59000
3	46	19565	13800	2.18	26201	4770	64336	69000
4	30	20000	15000	2.28	34125	5650	74775	75000
Sum	-	75693	50100	-	89201	15501	230495	250500

From table 4.3 we see that the order sizes have been reduced as they have to since the capital has been reduced with 100000. Consequently, the order costs have increased, but the cyclic inventory holding costs have decreased. The service levels have become larger, then has also the cost of keeping a safety stock. The stock-out costs have only increased marginally. The probability of experiencing a stock-out situation has been reduced somewhat, but the number of order cycles has increased. Compared to the unrestricted case, the total logistical costs have increased with 6949, corresponding to an interest rate equal to almost 7%. Therefore, if one could place 100000 in a bank to a higher interest rate one should do this.

Note also that from (13) we find the Lagrangian multiplier to be $\lambda = 0.1916$.

We then turn to the P2 (fill rate situation). In this case the stock out costs will depend on the number of units than cannot be delivered directly from shelf. These costs are estimated as a certain percentage of the unit value, that is, as money per unit. In the calculations below these percentages are taken as 25, 35, 35 and 40 for item 1, 2, 3, and 4, respectively. The calculations are based on the formulas (6) and (7).

Table 4.4. Optimal order sizes and associated cost elements for the four items in the unrestricted case with P2 service concept

Item	Q_{UR2}	Order costs	Cyclic inventory holding costs	Safety factor z	Cost of safety stock	Stock-out costs	Logistical costs	Average capital in cyclic inventory
1	132	11364	13200	1.73	8650	2011	35225	66000
2	85	14118	17000	1.98	15840	2951	49909	85000
3	63	14286	18900	1.98	23760	4479	61425	94500

4	41	14634	20500	2.04	30600	5578	71312	102500
Sum	-	54402	69600	-	78850	15019	217871	348000

From table 4.4 we see that the total logistical costs for this family are 217871 and that the average capital tied up in the cyclic inventory is 348000. An example of how to calculate the optimal pair, that is, the optimal order quantity and the service level, can be found in the appendix. We also note that the P2 service levels are pretty high and above 99 % for all four items. The stock-out costs are substantially smaller than the cost of keeping a safety stock. The order sizes are larger than the Harris-Wilson quantities as shown theoretically. It is also worth to notice that the capital tied up in the safety stock is roughly at the same level as the average capital tied up in the cyclic inventory

Now assume that we want to reduce this capital with 50000, that is, to C=298000. In order to obtain this, the order sizes must be reduced. Using (14), the ratio 298000 : 348000 = 0.856 the optimal order sizes from table 4.4 we get the optimal order sizes for the restricted case and the associated costs and service levels in table 4.5.

Table 4.5. Optimal order sizes and associated cost elements for the four items in the restricted case with P2 service concept and restriction on capital equal to C = 298000

Item	Q_{R2}	Order costs	Cyclic inventory holding costs	Safety factor z	Cost of safety stock	Stock-out costs	Logistical costs	Average capital in cyclic inventory
1	113	13274	11300	1.80	9000	1975	35549	56500
2	73	16438	14600	1.96	15680	3623	50341	73000
3	54	16667	16200	1.98	23760	5225	61852	81000
4	35	17143	17500	2.04	30600	6534	71777	87500
Sum	-	63522	59600	-	79040	17357	219519	298000

The Lagrangian multiplier becomes $\mu = 0.073$

By reducing the capital, the total logistical costs increase from 217871 to 219519, that is, 1648. By reintroducing the capital of 50000 one could save 1648. This corresponds to 3.3%. Hence, if the interest rate obtained by putting money in a bank is smaller than 3.3% one should not reduce the capital.

5. CONCLUSIONS AND FURTHER RESEARCH

In this paper we have shown that it is possible to find optimal pairs for each item in a family under restriction of the average capital tied up in the cyclic inventory both in the P1 and in the P2 stock out situations. The solutions show that it is not necessary to perform new iteration processes in these cases. The new and reduced order quantities can be obtained directly from the unrestricted cases by multiplying these by the fraction obtained by dividing the restricted capital C by the average capital tied up in the family in the unrestricted case. We have also obtained explicit formulas for the Lagrangian multipliers in both cases. However, the starting point is the average capital tied up in the **cyclic** inventory, not in the safety stock. The examples show that the capital tied up in the safety stock can be substantial. Ideally this capital should have been included in the models. On the other hand, it is not straightforward to include these added properties into the models treated here and obtain analytical formulas in these cases. There are other cases where the technique above probably could be applied. For instance the case where one has a family of items that is ordered in a coordinated way. That is, where all the items in the family is ordered at the same time from a supplier and received at the same time, but not include any restriction on capital. A similar case that could be of interest is the case where one has a restriction on the total number of orders for the given family, but ordered independently of each other.

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APPENDIX

Proof for the restricted case and P1 service concept:

The Lagrangian function is given in (10). The last term of this Lagrangian function does not contain the variables z_i. Hence, derivation with respect to these variables will give the same formulas as in the single item case, which are (12). Observe that in order to prove these formulas we use the following result $\frac{\partial p_{u\geq}(z)}{\partial z} = -\frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$

Now, derivation of the Lagrangian function (10) with <u>respect</u> to $(Q_{R1})_i$ and assuming that these derivatives are equal to zero one gets

$$-\frac{d_i}{(Q_{R1})_i^2} A_i + \frac{1}{2} v_i r - \frac{d_i B_{1i}}{(Q_{R1})_i^2} p_{u\geq}(z_i) + \frac{1}{2} \lambda v_i = 0$$

which is easily transformed to (11) by solving the above equations with respect to the order quantities

$$(Q_{R1})_i = \frac{1}{\sqrt{r+\lambda}} \sqrt{\frac{2d_i(A_i + B_{1i} p_{u\geq}(z_i))}{v_i}} = \frac{\sqrt{r}}{\sqrt{r+\lambda}} \sqrt{\frac{2d_i(A_i + B_{1i} p_{u>}(z_i))}{r v_i}} =$$

$$\sqrt{\frac{r}{r+\lambda}} \sqrt{\frac{2d_i A_i}{r v_i} + \frac{2d_i A_i}{r v_i} \frac{B_{1i}}{A_i} p_{u\geq}(z_i)} = \sqrt{\frac{r}{r+\lambda}} (Q_{HW})_i \sqrt{1 + \frac{B_{1i}}{A_i} p_{u\geq}(z_i)} = \sqrt{\frac{r}{r+\lambda}} (Q_{UR1})_i$$

Using the first formulation of (11) combined with the assumption $\frac{1}{2}\sum_{i=1}^{n}(Q_{R1})_i v_i = C$ gives the following equation:

$$\frac{1}{2}\frac{1}{\sqrt{r+\lambda}}\sum_{i=1}^{n}\sqrt{\frac{2d_i\left(A_i + B_{1i}p_{u\geq}(z_i)\right)}{v_i}}v_i = C$$

By taking the power of two on both sides, one obtains (11). Now using the constraint in the Lagrangian model in combination with the last part of (11) we get the last part of (13):

$$\sqrt{\frac{r}{r+\lambda}}\frac{1}{2}\sum_{i=1}^{n}(Q_{UR1})_i v_i = C \Leftrightarrow \frac{r}{r+\lambda}\left(\sum_{i=1}^{n}(Q_{UR1})_i v_i\right)^2 = 4C^2 \Leftrightarrow \lambda = \left(\left(\frac{\sum_{i=1}^{n}(Q_{UR1})_i v_i}{2C}\right)^2 - 1\right)r \Leftrightarrow$$

$$\lambda = \left(\left(\frac{C_{UR1}}{C}\right)^2 - 1\right)r$$

Proof for the restricted case and P2 service concept:

The Lagrangian function is given in (17). The last term of this Lagrangian function does not contain the variables z_i. Hence, derivation with respect to these variables will give the same formulas as in the single item case, which are (19). Observe that in order to prove these formulas we use the following result $\frac{\partial G_u(z)}{\partial z} = -p_{u\geq}(z_i)$

Now, derivating the Lagrangian function (17) with <u>respect</u> to $(Q_{R2})_i$ and assuming that these derivatives are equal to zero one gets

$$-\frac{d_i}{(Q_{R2})_i^2}A_i + \frac{1}{2}v_i r - \frac{d_i B_{21} v_i \sigma_i G_u(z_i)}{(Q_{R2})_i^2} + \frac{1}{2}\mu v_i = 0$$

which is easily transformed to (18) by solving the above equations with respect to the order quantities

$$(Q_{R2})_i = \frac{1}{\sqrt{r+\mu}}\sqrt{\frac{2d_i\left(A_i + B_{2i}v_i\sigma_i G_u(z_i)\right)}{v_i}} = \frac{\sqrt{r}}{\sqrt{r+\mu}}\sqrt{\frac{2d_i\left(A_i + B_{2i}v_i\sigma_i G_u(z_i)\right)}{rv_i}} =$$

$$\sqrt{\frac{r}{r+\mu}}\sqrt{\frac{2d_iA_i}{rv_i} + \frac{2d_iA_i}{rv_i}\frac{B_{2i}v_i\sigma_i G_u(z_i)}{A_i}} = \sqrt{\frac{r}{r+\mu}}(Q_{HW})_i\sqrt{1+\frac{B_{1i}}{A_i}v_i\sigma_i G_u(z_i)} = \sqrt{\frac{r}{r+\mu}}(Q_{UR2})_i$$

Using the first formulation of (18) combined with the assumption $\frac{1}{2}\sum_{i=1}^{n}(Q_{R1})_i v_i = C$ gives the following equation:

$$\frac{1}{2}\frac{1}{\sqrt{r+\mu}}\sum_{i=1}^{n}\sqrt{\frac{2d_i\left(A_i+B_{1i}v_i\sigma_i G_u(z_i)\right)}{v_i}}v_i = C$$

By taking the power of two on both sides, one obtains the first part (20). Now using the constraint in the Lagrangian model in combination with the last part of (18) we get the last part of (20):

$$\sqrt{\frac{r}{r+\mu}}\frac{1}{2}\sum_{i=1}^{n}(Q_{UR2})_i v_i = C \Leftrightarrow \frac{r}{r+\mu}\left(\sum_{i=1}^{n}(Q_{UR2})_i v_i\right)^2 = 4C^2 \Leftrightarrow \mu = \left(\left(\frac{\sum_{i=1}^{n}(Q_{UR2})_i v_i}{2C}\right)^2 - 1\right)r \Leftrightarrow$$

$$\mu = \left(\left(\frac{C_{UR2}}{C}\right)^2 - 1\right)r$$

Example for calculating the optimal pair in the unrestricted case for P1using item 2 as an illustration.

The tables for the normal distribution in Silver et al (1998) are used in the table below.

Order size Q (Starting with the Harris- Wilson quantity	Safety factor z	$p_{u\geq}(z)$	$1+\frac{B_1}{A}p_{u\geq}(z)$
77	2.13	0.01659	1.2233
82	2.10	0.01786	1.1488
83	2.10	0.01786	1.1488

Example for calculating the optimal pair in the unrestricted case for P2using item 4 as an illustration.

The tables for the normal distribution in Silver et al (1998) are used in the table below.

Order size Q (Starting with the Harris- Wilson quantity	$p_{u\geq}(z)$	Safety factor z	$G_u(z)$	$1+\frac{B_2}{A}v\sigma G_u(z)$

35	0.01750	2.11	0.006292	1.3146
40	0.02000	2.05	0.007418	1.3709
41	0.02050	2.04	0.007623	1.3815
41	0.02050	2.04	0.007623	1.3815

EMERGENCY RESPONSE LOGISTICS

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EMERGENCY RESPONSE LOGISTICS

ABSTRACT

Purpose – Emergency response logistics is an emerging field of interest among practitioners and academics, but we lack theoretical foundations. The purpose is to use insights from logistics and supply chain management to propose a theoretical point of departure and to point to interesting research opportunities.

Design/methodology/approach - Literature review and conceptual discussion.

Findings – Emergency response logistics should address 1) the forwarding (and withdrawal) of emergency response resources, and 2) the cooperation among the members in the emergency response network. Emergency response logistics research is scarce, except for studies in humanitarian logistics.

Research limitations/implications - Recommendations for further research include the study of logistical performance and collaboration among emergency response network members taking the network as the unit of analysis.

Practical implications - Insights from logistics and supply chain management can improve the effectiveness of emergency networks.

Social implications – Developing knowledge on emergency response logistics has the potential to improve emergency response logistics, and thereby reduce damages (related to life/health, material valuables or nature/environment) caused by unwanted incidents.

What is original/value of paper - The logistics and supply chain management literature has addressed humanitarian crises but not 'everyday' emergency response, such as fires, car accidents, and oil spill. This paper fills some of this gap.

Keywords: Emergency network, structure, organization, effectiveness, emergency response logistics

1. INTRODUCTION

In evaluations of emergency response, the common main conclusion is that there is a lack of cooperation among emergency actors (Pettit *et al.*, 2011; Sverdrup, 2013). The problem is not a lack of commitment or lack of qualifications, and several observers point to poor emergency response logistics. Emergency logistics has, it seems, become a new word, particularly among practitioners.

As a consequence, the demand for courses in emergency response logistics has urged some universities to offer such courses, but the topic has not yet been established as a scientific discipline, and there is currently no academic texts treating the subject in full.

While the large crises have attracted academic attention, minor unwanted incidents have not (McLennan *et al.*, 2006). One reason for this is that these incidents are not interesting for research because they will not provide useful data for analysis (Sjøberg *et al.*, 2006). In general, little data from unwanted incidents are collected at the site of the incident for the purpose of research. Research on emergency response therefor is characterised by retrospective studies, but only of major, large scale unwanted incidents (Palm and Ramsell, 2007). One exception is Berlin and Carlström (2008) that assess cooperation among three emergency response actors (police, fire workers and ambulance) during training on four different occasions.

Even research on crises suffers from a lack of definition of different types of crises (Quarantelli, 1998), but Hermitte et al. (2014) suggested a classification model for disasters reflecting different logistics implications. Such definition is the first step toward, for example, theorising on how different types of crises are best handled by different types of emergency response logistics.

Some authors argue that most preparedness and emergency work basically concern logistics, like for example Moore and Taylor (2011). Not least when infrastructure is damaged, the transportation capacity is reduced, or the ability to provide help and assistance is reduced on other grounds, the lack of logistics becomes apparent to everybody (Kovacs, Tatham and Larson, 2012; Moore and Taylor, 2011). The emergency response actors themselves also express that they recognise the importance of logistics in emergency response (Altay and Labonte, 2011; Moore and Taylor, 2011). In humanitarian crises, logistic costs have been estimated to account for 80% of total emergency response costs (Wassenhove, 2006).

The purpose of this paper is to contribute to the development of emergency response logistics, by suggesting a theoretical point of departure drawing on insights from logistics and supply chain management. Emergency response logistics is considered as broader than humanitarian logistics. In addition to humanitarian logistics, emergency response logistics treat smaller unwanted incidents, and incidents that have the potential to damage the nature/environment or material valuables. Normally, emergency response is carried out by three or more organisations, and these are referred to as an emergency response network. Accordingly, this paper aims to contribute to further study of emergency network effectiveness.

2. EMERGENCY RESPONSE

In essence, emergency response concerns dealing with unwanted incidents. Unwanted incidents are either caused by man or nature, and threat life, health, environment or other valuables (Wassenhove, 2006). Such incidents come in many kinds, ranging from everyday car accidents to tsunamis, such as the one in South-east Asia in December 2004 that caused

death to 230.000 (estimate) human beings, according to USGS (2006). Indications are that weather and climate will cause more incidents in the years to come, so earth-quakes, tsunamis, storms etc. will require more emergency response compared to the past (Bournay, 2007).

At a national level (see e.g. DSB, 2015), a range of unwanted incidents are considered, ranging from minor accidents to humanitarian disasters.

Preparedness and emergency work is commonly described by four phases of action; mitigation, preparedness, response and recovery (Mileti, Drabek and Haas, 1975; Lindell, Prater and Perry, 2007), as illustrated in Figure 1. Mitigation is the effort for implementing measures apt at avoiding the occurrence of some (but not all) unwanted accidents. It is generally considered that it is unrealistic (and to expensive) to aim to reduce the occurrence of an unwanted incident to zero (Auf der Heide, 1989). Preparedness is planning and training for responding to unwanted incidents. Not every possible incident can be prepared for, and when these occur, the emergency network needs to plan as they process in the emergency response. Response is the attempt to keep losses as low as possible, either in terms of life, health, environmental or other valuables. Recovery is the phase where it is sought to re-establish 'the normal situation' to the extent that it is possible, including reverse logistics.

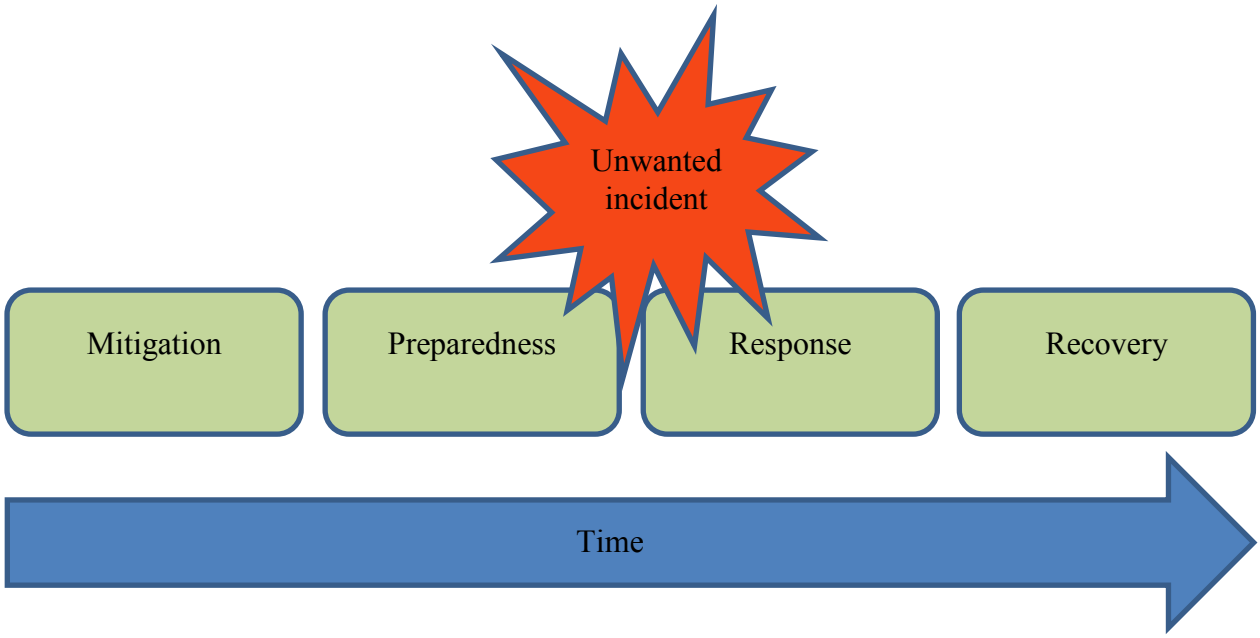


Figure 1. Phases in emergency work

3. EMERGENCY RESPONSE LOGISTICS

As early as 20-years ago, Long and Wood (1995) pointed to the need for emergency response logistics, but it was not until the aftermath of the 2004-tsunami in South-east Asia that humanitarian logistics started emerging as a logistics discipline. Humanitarian logistics is defined by Thomas and Kopczak, 2005: p.2) as:

> *The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people. The function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance.*

This is a wide definition that applies to minor unwanted incidents as well as humanitarian disasters, in which life and health is threatened. From a logistical point of view it is interesting to note that the definition concerns goods and materials, but not other emergency response resources, such as staff and heavy equipment (as well as other resources for supporting the staff and staff activities). Furthermore, logistics is treated as forwarding goods and materials to the site of the incident.

Tovia (2007) offers a similar definition of logistics in natural disasters. Apte (2009) explains humanitarian logistics as a branch within logistics dealing with large-scale operations supplying critical goods and services under harsh conditions, unpredictable demand, uncertain access to goods, and critical time-windows due to damaged or destroyed infrastructure. In contrast to business logistics, humanitarian logistics must handle more uncertainty (as the unwanted incidents cannot be accurately predicted), there are no customers paying for the goods or services, and it makes little sense to address customer needs (Walker and Russ, 2010), and failures can have fatal consequences (Christopher and Tatham, 2011).

One weakness with this perception of emergency response logistics is that logistics is not related to cooperation at the site of the incident. Logistics ends where emergency response work starts. Such emergency response work is of course made possible by the resources that have been forwarded to the site of the incident.

Another weakness is that only life and health concerns are addressed. In emergency response also environment and other valuables are important. At a national level (see e.g. DSB, 2015), a range of unwanted incidents are considered, ranging from minor accidents to humanitarian disasters. Humanitarian logistics also addresses major humanitarian disasters, but not minor incidents. Humanitarian logistics can therefore be considered as an extreme form of emergency response logistics, with regard to life and health issues.

An obvious alternative perspective is to adopt a supply chain management perspective, because the emergency network is responsible for the emergency logistics. Council of Supply Chain Management Professionals (CSCMP) (2013) defines supply chain management as:

> *Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. […]."*

Perceiving emergency response logistics as supply chain management directs attention to the emergency response network and how this operates as a single social unit. In addition to highlighting the flow of goods and materials, this definition incorporates the importance of inter-firm cooperation between the emergency response actors, but also third parties, such as

for example transportation agencies. This view on emergency response logistics is illustrated in Figure 2.

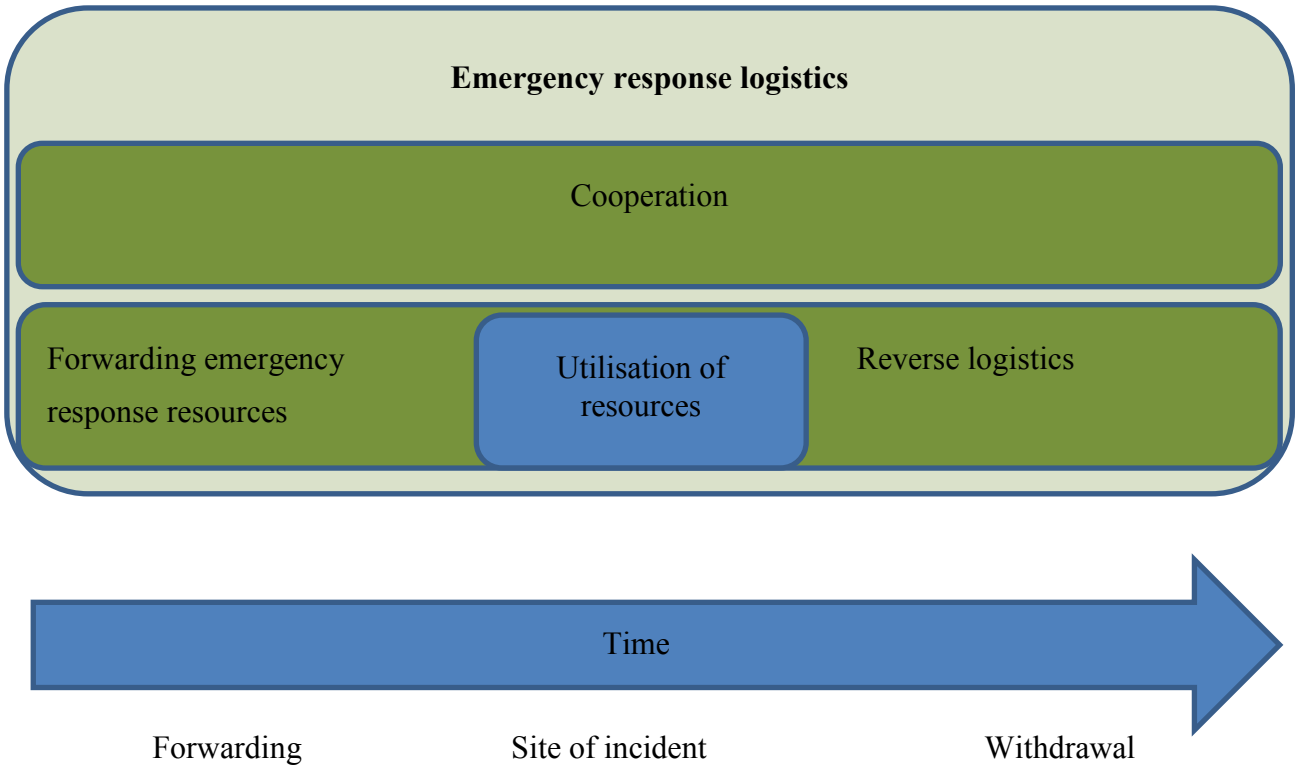


Figure 2. Emergency response logistics.

The flow of goods and materials in emergency response logistics can be describes as in Figure 4. In addition to the direct flow to the site of the incident from emergency inventories, there are possible flows to support the emergency staff, including directly from suppliers.

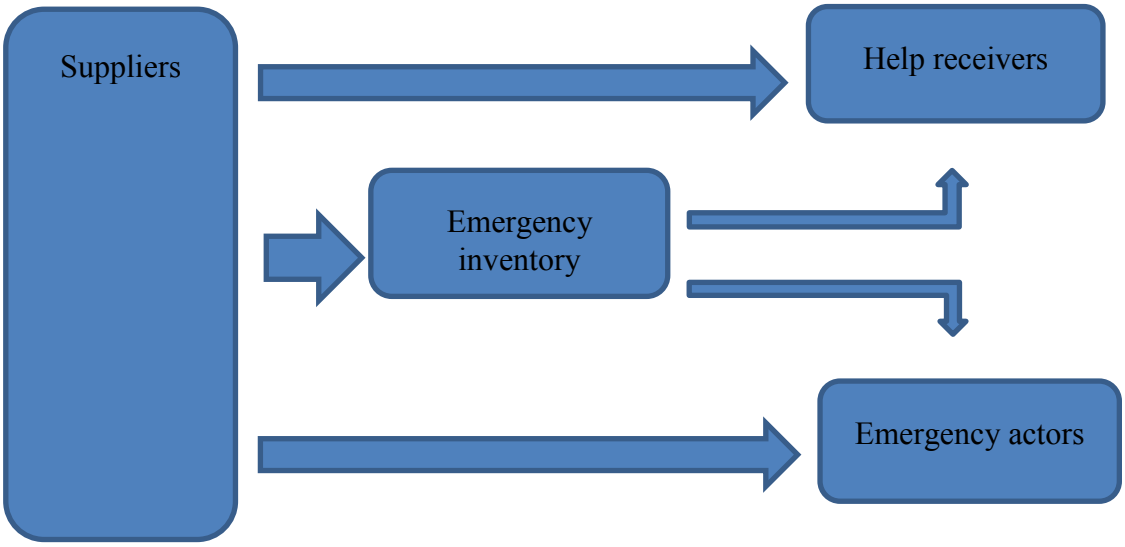


Figure 4. Flows of goods

4. EMERGENCY NETWORK EFFECTIVENESS IN FORWARDING

The performance of emergency response logistics can be evaluated the same way as traditional business logistics, with the exception of adapting to customer needs. The idea of adapting to individual customer needs make more sense in a commercial setting, but in an emergency the receiver of help does not pay for the offering. Based on Persson and Virum (2011), the six other dimensions of logistic service can be adapted (by slight name changes):

a. Response level
b. Response time
c. Response accurateness
d. Response reliability
e. Information exchange
f. Response flexibility

a) Response level

The response level is the probability that an emergency resource is available at the site of the unwanted incident when it is needed. Response level can be defined in different ways. For deliveries from an emergency inventory can it be defined as the percentage of requests that are fully satisfied. An alternative measure is the number of unwanted incidents that are fully served as a percentage of the total number of unwanted incidents that requested the good in question (Waters, 2011). The latter approach is the most practical; it is easier to calculate in practice.

Previous studies has operationalized response level in terms of the number of rescue flights as compared to the number of requested rescue flights (Hag, Åvall, and Monsen, 2009), and Brodsky and Hakkert (1983) investigated the availability of ambulances (measured as good, medium or low).

b) Response time

The response time describes the time lag between need recognition and delivery at the site of the unwanted incident. Response time can also be sub-divided into e.g. administrative response time, to study its components. It can also be applied to individual actors in the emergency network, but such measures do not necessarily offer meaningful descriptions of the network as a whole.

Response time has been measured in many previous studies with regard to first aid in traffic accidents (Alexander *et al.*, 1984; Brodsky, 1990; Bigdeli *et al.*, 2010; Drakopoulos, Shrestha, and Örnek, 2007). Isenberg and Bissel (2005) call for more research on which response time is required for utilizing expensive first aid for different types of human injuries. Nevertheless, previous research has found that shorter response time is better for those in need of help: Brodsky (1990) found that the death rate increased from 3.9% to 8.3% when response time increased from 5 to 30 minutes (or more).

c) Response accurateness

Response accurateness means that the right product, in right quantity is forwarded to the site of the unwanted incident. If the wrong products are sent, or products are damaged during transportation, response accurateness suffers.

d) Response reliability

Response is reliable if it is delivered when it is due. In practice, response reliability means that the expected response time can be trusted. Response reliability is important for refilling emergency inventory, but at the site of an unwanted incident what matters is the response time.

e) Information exchange

Information is required for assuring efficient product flows. The better oversight, the easier to avoid bottlenecks, and reduce unnecessary waiting times and to assure that the right products arrive in time at the site of the unwanted incident. Recently, academic writers have addressed exchange of accurate information in emergency networks (Dorasamy *et al.*, 2012), e.g. by means of social media (van de Walle and Dugdale, 2012).

f) *Response flexibility*

Response flexibility denotes the emergency network's ability to adapt to new contingencies without reducing the network's performance (Upton, 1995). By new contingencies is meant new conditions that arise (or become apparent) after the emergency operation has started at the site of the unwanted incident. The larger the changes that can be accounted for, the larger the emergency network's response flexibility.

Response flexibility can be enhanced by proactive planning (Sawhney, 2006), and is related to the level of specification in emergency response tasks; the better specified in advance, the easier to plan, and the less need for flexibility.

In sum, with the exception of response time, effectiveness in emergency networks, with regard to forwarding of emergency resources, is scarce. Perceiving emergency logistics in terms of the six dimensions as suggested by Persson and Virum (2011) offers rich opportunities for doing research on forwarding emergency resources in emergency networks.

5. EMERGENCY NETWORK EFFECTIVENESS IN COOPERATION

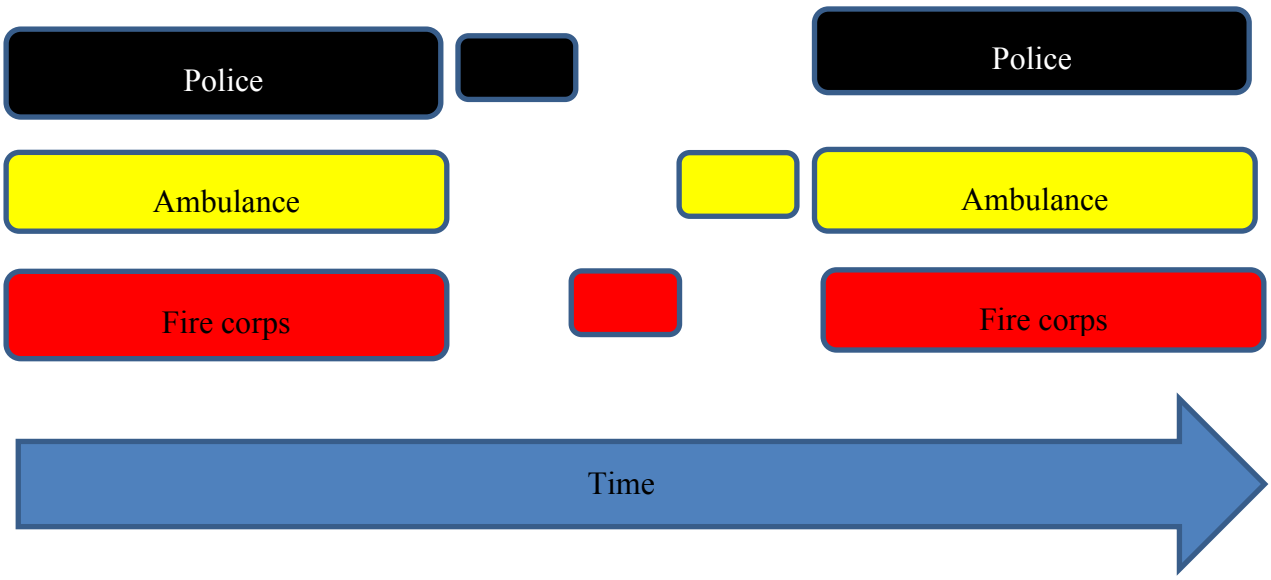
Cooperation among emergency response actors depends on the complexity of the network, its organization, as well as its governance and management. Taking an instrumental approach, the network has a technology – that is methods, knowledge and resources that allows it to carry out the emergency response (Perrow, 1967). At a fundamental level the network is organized with pooled, sequential or reciprocal interdependencies among the actors (Thompson, 1967).

Pooled interdependence means that actors in the network perform their tasks irrespective of other actors' activities. If one actor does not carry out its activities as expected, other actors' performance is not affected, but the emergency network's performance is reduced.

Thompson (1967, p.54) gives the following example of sequential interdependence involving the Keokuk plant that produces parts that are inputs for the Tucumcari assembly operation: "Keokuk must act properly before Tucumcari can act; and unless Tucumcari acts, Keokuk cannot solve its output problem." The key coordination concern in sequential interdependence is technical and administrative coordination (Borys and Jemison, 1989). To achieve this, the parties must understand their partner's logistical operations if they are to achieve transparency and boundary permeability. This entails effective inter-organisational communication, including personal interactions between buying personnel and selling personnel (Chen and Paulray 2004).

Reciprocal interdependence involves mutual learning (Dyer and Singh 1998). For example, in an airline that combines an operational unit with a maintenance unit, Thompson (1967, p. 55) observed that "… the production of the maintenance unit is an input for operations, in the form of a serviceable aircraft; and the product (or by-product) of operations is an input for maintenance, in the form of an aircraft needing maintenance". In contrast to sequential interdependence, such reciprocal interdependence requires on-going mutual adjustments by both parties and continuous adaptation to each other's circumstances (Gulati and Singh 1998).

In pooled interdependence, cooperation means obedience to rules and standard operation procedures. When there is sequential interdependence, Borys and Jemison (1989) suggested that cooperation occurs at the points of contact between the two organisations through an operational linkage. This was defined by Simatupang *et al.* (2002) as the interface between supply chain partners, at which they integrate and coordinate their interdependent processes and information flows, thus enabling them to carry out logistics planning and day-to-day transactions. Sequential interdependence thus requires coordination between the buying firm's inbound logistics and the selling firm's outbound logistics - including such activities as receiving, storing, distributing, material-handling, delivery-vehicle operations, order processing, and so on (Porter 1985). Value creation is enhanced if supply chain partners make transaction-specific investments, undertake other adaptations, identify and motivate 'right' actions from each other, and exchange information for planning purposes (Hammervoll, 2009). Sequential interdependence in emergency response is illustrated in Figure 5.



Forwarding Site of incident Withdrawal

Figure 5. Sequential interdependence at site of incident

In the case of reciprocal interdependence, coordination requires more centralised organisational interaction (beyond the points of contact) (Borys and Jemison 1989). The establishment of a successful organisational linkage implies that supply chain partners gain knowledge about each other's organisations in terms of decision-making procedures, preferences, and so on (Simatupang *et al.* 2002). This cannot be achieved in operational linkages. Organisational linkages can involve coordination of technology-development activities between the two firms - including efforts to improve products and efforts to improve processes (Porter 1985). Knowledge-sharing between the firms (mainly at the organisational level) and a willingness to combine complementary resources for synergies, increase the potential for value creation (Hammervoll, 2009). Reciprocal interdependence in emergency response is illustrated in Figure 6.

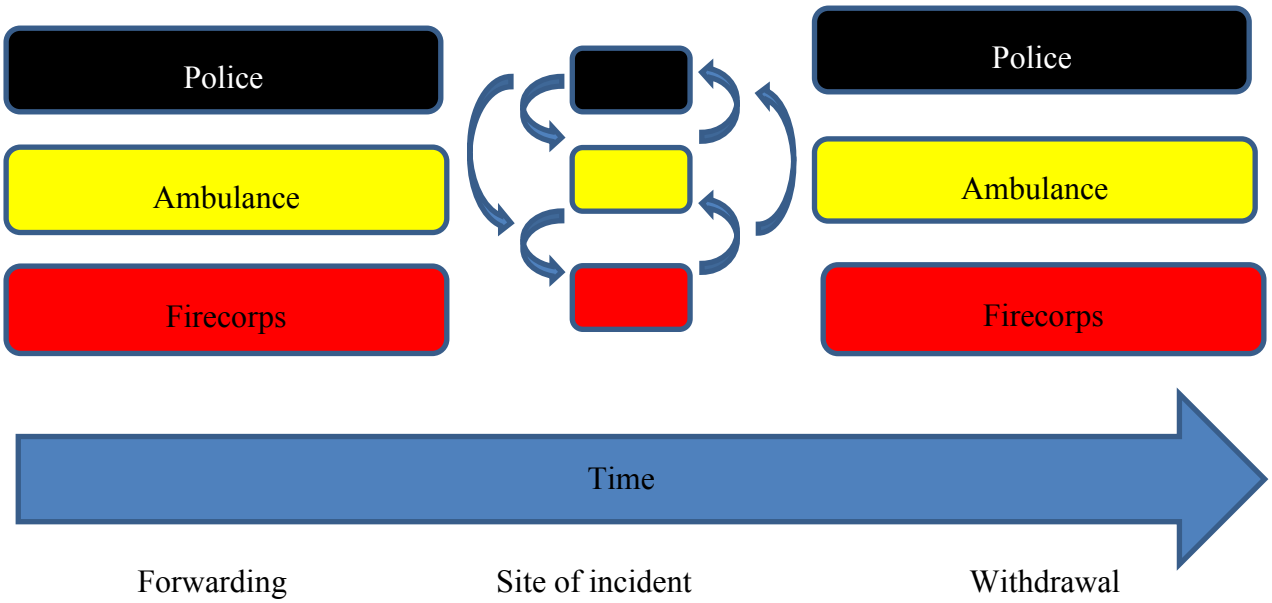


Figure 6. Reciprocal interdependence at site of incident

There is no known evaluation of cooperation at the site of the incident according to different types of interdependence types. Such evaluation should evaluate pooled interdependence by assessing the actors' obedience of rules and standard operating procedures. Sequential interdependence should be assessed in terms of the actors ability to perform their value adding activities according to plan. Finally, in reciprocal interdependence the actors' trust and confidence in each other indicate to what extent they are able to resolve issues that require mutual adaptations (Thompson, 1967).

The various information flows associated with the utilisation of resources at the site of the incident, information for coordination, site information and medical information, are illustrated in Figure 7.

1) Information for coordination

Information exchange required for coordination at the site of the incident varies according to the type of interdependence among the emergency response actors. For example, some activities at the site needs to be performed in a certain sequence (interdependence is sequential), as when a medical care unit cannot perform its work before the police has secured the site.

2) Site information

The Site information should ideally contain the complete information or overview of the situation. This will typically be the size of the incidents, severity, society impacts etc. This information is normally held by the police that also gives the information to a second level in case of the need for more resources. The second level of police may have the responsibility for information to the society or media as well as to consider if more resources like army or other organizations. The information to the second level police is given directly from police at the site. The information will continuously be updated from the site.

3)Medical information

The medical information is given form the health care unit on site to nearby hospitals or a hospital coordination central. The information contains the number of patients and the severity of the incidents for all patients and given directly from the health care unit. The coordination central will use the information to consider in-hospital resources.

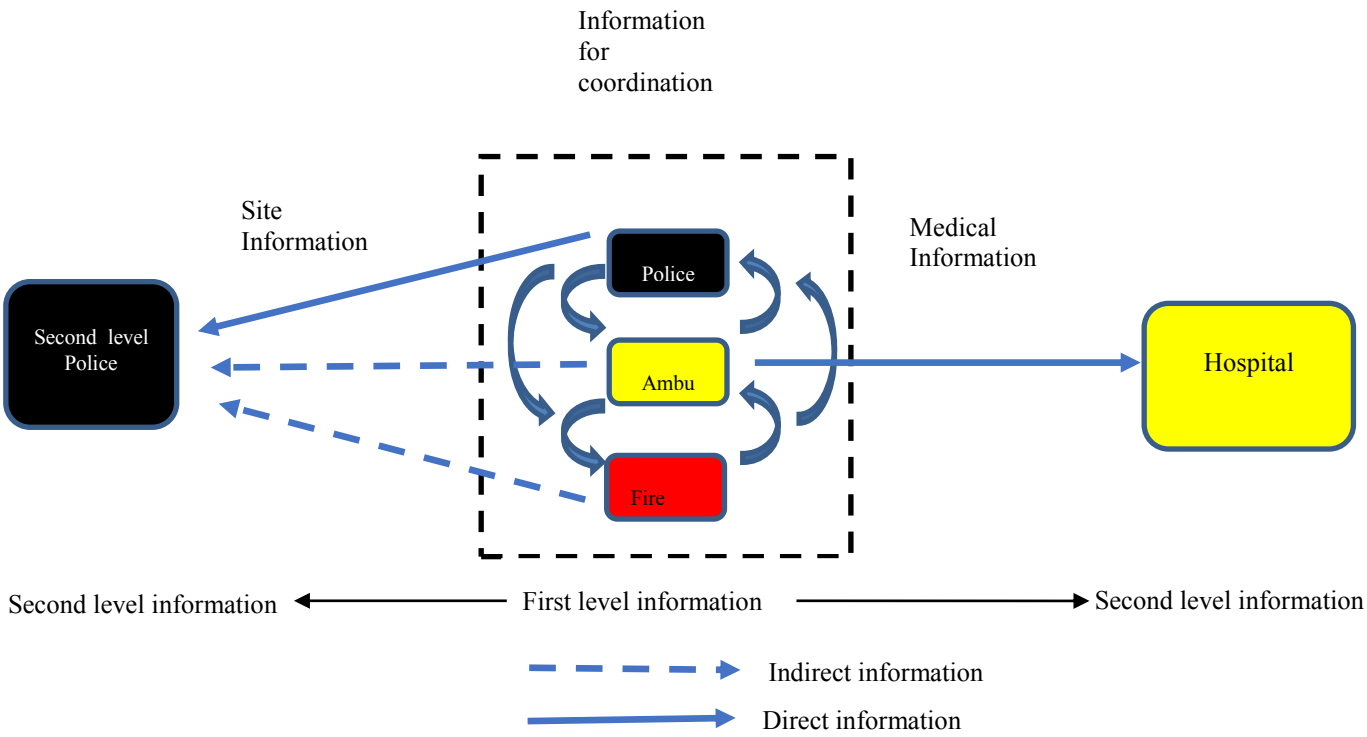


Figure 7. Information flows associated with the utilisation of resources at the site of the incident

6. CONCLUSION

This paper suggests a theoretical point of departure for emergency response logistics departing from the emergency response network of actors studied as a social unit. In addition to highlighting the flow of goods and materials, the proposed definition of emergency response logistics incorporates the importance of inter-firm cooperation between the emergency response actors, but also third parties, such as for example transportation agencies. This definition also distinguishes emergency response logistics as a broader phenomenon compared to humanitarian logistics – humanitarian logistics is considered as an extreme case of emergency response logistics.

Emergency network effectiveness has barely been addressed in previous research. Mostly, response time has been assessed in some studies, mainly with regard to traffic accident. This paper suggests additional aspects to investigate in further research. These suggestions are rooted in traditional business logistics, encompassing assessing additional service dimensions such as response flexibility, accurateness, reliability etc.., as well as assessing the level of cooperation in the emergency network.

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Efficiency and effectiveness drivers in wholesale transport

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ABSTRACT

Purpose
Transport in wholesale is a core business function that should be efficient and effective. To cope successfully with the growing trade-off between rising transportation costs and increasing customer's logistical requirements, wholesalers need to improve their transport performance. Therefore, this research aims at providing a cause-and-effect analysis to explore influencing factors on wholesale transport performance.

Design/methodology/approach
Grounded theory as an inductive, holistic method is used to explore cause-and-effect relationships on transport performance at operational, tactical and strategic levels. Eight interviews are conducted with transport leaders and/or general managers in wholesale.

Findings
The paper presents a framework of transport management processes and activities of wholesalers: at an operational level, process standards and clearly assigned tasks are missing or not met. Planning for transport operations rarely exists at tactical level. Strategically, transport management has a subordinate role in wholesale.

Research limitations/implications
This analysis is conducted with German wholesalers of production-related products. Findings have to be verified for other wholesaling sectors. Future research needs to check qualitative findings with a larger sample.

Practical implications
The results provide recommendations for wholesalers how to reconsider transport management to work more efficiently and better meet customer satisfaction.

Original/value
To our knowledge, the paper presents a novel framework which considers cause-and-effects on transport performance for the first time within a holistic approach.

Keywords: transport, wholesale, efficiency, effectiveness, transport performance

1. MOTIVATION

Wholesalers meet challenges in their business environment due to a growing tradeoff between rising customer demands in terms of logistical requirements and increasing transport costs (Lau, 2012). Prior research shows that transportation in wholesale has a significant impact on the entire profitability of wholesalers (Germain and Dröge, 1990). Additionally, Innis and La Londe (1994) find statistical evidence that customer service in physical distribution is most important for wholesaling customers. Furthermore, problems in transport management within wholesale companies become evident (Lau, 2012; de Leeuw *et al.*, 2013). Customer's power and competition in wholesale is considered very high. Therefore, an excellent performance in transport logistics can help to obtain a competitive advantage. For this purpose, it is necessary to know which factors influence transport performance and how transport performance can be improved.

Logistics performance is scientifically widely seen as a key success factor in competition (Fugate *et al*., 2010). Especially distribution logistics directly affect company's performance because of its influence on costs and customer satisfaction (Tracey, 2004; Lau, 2012). Logistics activities of wholesaling companies represent core processes in wholesaling. In this context, transportation costs constitute the largest part of all logistics costs. Transport as the last link in the wholesaler's logistic chain illustrates the overall logistics performance and represents an interface to the customer (Tyagi and Das, 1995). Consequently, wholesalers have to show both, transport efficiency and responsiveness to customers.

Literature in wholesale is scarce and a need for further supply chain research with regard to distribution in wholesale has been stated repeatedly (Germain and Dröge, 1990; Lau, 2012, de Leeuw *et al.*, 2013). In many practical and scientific studies transport logistics is considered to be inefficient (Arvidsson *et al*., 2013 provides an overview). Within prior research, often only isolated aspects have been studied and causes of transport inefficiencies remain unexplored (McKinnon 2009; Sternberg *et. al*., 2012). Finally, there is a current need to investigate performance evaluation taking a holistic view (Akyuz and Erkan, 2010).

Therefore, two research questions are raised:

- RQ1: What do transport management processes and activities of wholesaling companies look like?
- RQ2: What are influencing factors on transport management performance of wholesaling companies?

This contribution is structured as follows: First, we provide an overview of the state of the art concerning literature on transport logistics in wholesale and performance measurement in transport. In the subsequent section, grounded theory as the methodology of our qualitative research is presented. In chapter four, we elaborate a framework which illustrates processes and activities of transport in wholesale and which forms the basis for the cause-and-effect analysis on transport performance. Causes of transport performance are considered from an efficiency and an effectiveness point of view. Afterwards, correcting actions regarding causes of transport performance are deduced and they are revised on operative, tactical and strategic levels. Finally, we provide some theoretical and managerial implications and suggest paths for future research.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

First, existing logistics and transport literature has been reviewed. In this study, we use the online database EBSCO as a search tool to identify relevant publications. Well ranked logistics and transportation journals are selected based on established journal rankings provided within the Journal Quality List compiled by Harzing (2014). In a second step, after reviewing the selected literature, the compilation is completed with further journals in the transportation and logistics field and those articles from other disciplines that deal with relevant aspects of our research question. In logistics science, it is argued that scholars should better focus on the impact of articles rather than only on journal rankings (McKinnon, 2013). The relevance of the papers is judged by two researchers who evaluate the contributions by title, keyword and abstract.

2.1. Transport logistics in wholesale

More than half of the EU wide trade is related to wholesaling. The largest part of European turnover in wholesale is done in Germany (Eurostat, 2004). Wholesalers serve as an intermediary between upstream manufacturers and downstream customers. The primary value added of wholesaling companies consists of advisory services followed by logistics (Tyagi and Das, 1995). Especially smaller customers use logistics services increasingly in order to reduce their own inventory. In Germany, the wholesale sector is nearly equally divided in terms of turnover in its two wholesaling sectors: wholesaling of consumer goods and production related trading. Different types of wholesalers make it difficult to generalize about their operations. Nevertheless, common wholesaling operations are "multidirectional logistics systems" that are "to some extent unique" (Germain and Dröge, 1990, p. 120). In wholesale, raw materials, semi-finished and some finished goods are stored between inbound and outbound shipments while being transformed to product assortments for customers. Core processes of wholesaling companies are procurement, sales, warehousing and transportation of goods (Tyagi and Das, 1995). The wholesaler's profitability depends not only on efficiency in purchase and operations but also on effectiveness in terms of responsiveness to customer needs. Prior research has empirically shown how transportation impacts the overall profitability of wholesalers (Germain and Dröge, 1990) with regard to costs and customer service (Innis and La Londe, 1994). Transport logistics in wholesale therefore constitutes a linking role within the supply chain. Wholesaler's primary function of creating demand in terms of product assortments together with servicing demand in terms of logistics operations, distinguishes wholesalers from logistics companies. Consequently, transport performance in wholesale affects not only efficiency in operations, but particularly customer satisfaction. High customers' power and strong competition characterize the wholesaling market and in particular small and medium sized companies (SMEs).

The European wholesaling market is characterized by some nationwide large players with a significant market share and a huge number of medium-sized regional wholesaling companies which share a small percentage of the market among themselves (Eurostat, 2004). Generally, medium-sized companies have size-related disadvantages with regard to financial and human resources and they do not benefit from important economies of scale and scope. However, compared to large firms, they are more dynamic and closer to their customers. Hence, it is easier for them to be customer oriented. Nonetheless, under competitive pressure, most companies adopt cost reduction strategies with only short term effects. According to prior research, permanently delivering high quality services to customers and being customer oriented is "significantly and positively related to business performance across a range of small- and medium-sized" companies (Appiah-Adu and Singh, 1998, p. 392). Therefore,

SMEs should try to obtain a sustainable competitive advantage by improving their supply chain logistics in order to better meet customer needs. However, many medium-sized companies lack competence in managing and purchasing transport services (Holter, 2008).

Transport processes and activities of wholesaling companies as well as their particularities compared to transport processes in other sectors are not yet depicted. Furthermore, only some isolated problems in literature in terms of transport in wholesaling have been stated. Thus, Lau (2012) indicates an underutilization of vehicle capacity especially due to non-consolidated orders. Consequently, small orders are unprofitable, because of the low invoice value. Furthermore, de Leeuw *et al.* (2013) state that there is high uncertainty in upstream markets which leads to high inventories to keep delivery times. The issues mentioned before show that even if future research regarding "the need for formal standardized evaluation of the transport management and purchasing function" has been stated for small and medium sized companies (Holter *et al*., 2008), it is important to take a holistic view on causes within the entire operation processes in wholesale. Consequently, prior to performance evaluation, there is a need of grounded inductive studies that look at causal aspects within companies with influence on processes (McAdam, 2002).

2.2. Performance in transport logistics

In today's business environment, logistics has evolved from a cost centre perspective towards a competitive advantage. Consequently, logistics performance evaluation is a "vital managerial function" (Mentzer and Konrad, 1991) which aims at improving one's competitive position. The term performance is not consistently used in literature. In the following, effectiveness is defined as the degree to which customer needs are met, whereas efficiency evaluates the utilization of resources (Fugate *et al.,* 2010). The term customer includes internal and external customers. Thus, transport performance is both: achieving customer satisfaction while economically utilizing resources. Both can be pursued at the same time. Therefore, to obtain competitive advantage, transport effectiveness and efficiency should be greater than those of one's competitors. In addition, some authors suggest logistics differentiation as a potential source of customer value.

In scientific literature, performance measures in distribution and transport logistics have been addressed by many authors (Caplice and Sheffi, 95; van Amstel and D'hert, 1996; van Donselaar *et al*., 1998). First, only internal indicators were considered, then supply chain metrics were subsequently included into consideration. Lai *et al*. (2004) examine supply chain performance in transport logistics. The study focusses on the self-assessment of transport logistics performance based on the SCOR model. Initially, the SCOR model was developed to analyze manufacturing processes. Hence, their contribution is an empirical measurement of supply chain performance in the transport logistics context. In prior transport research, many isolated issues of transport inefficiencies were investigated. Arvidsson *et al.* (2013) provide an overview of transport inefficiencies and various measures from the road haulers' point of view. In terms of transport productivity, various perspectives are considered in the literature. Stefansson and Lumsden (2009) develop a model of smart transportation management; Rodrigues *et al.* (2014) consider supply chain uncertainty and the impact of transport performance on supply chains and McKinnon and Ge (2006) examines productivity in regard to empty running problem. Although many problems in transport have been identified, findings are not yet successfully implemented. In general, real causes are not yet sufficiently investigated (McKinnon, 2009). Sternberg *et al*. (2012) state that "root cause analysis of waste in transportation […] remains unexplored". However, cause-and-effect relationships must be investigated taking into consideration tactical and strategic levels as well. Furthermore, most performance measures lack a supply chain view, but customer needs

within the distribution have to be taken into consideration. Moreover, performance measurement systems need to be connected with strategy and should be divided in strategic, tactical and operational levels in order to be successfully implemented (Gunesekaran and Kobu, 2007). Finally, there is a "need for [value based, client and long-term-oriented] performance measurement systems taking the holistic picture into account" (Akyuz and Erkan, 2010, p. 5150). As a result, it is necessary to examine cause-and-effects on transport performance from a holistic point of view.

3. METHODOLOGY

Research in supply chain management often includes complex phenomena at individual and organizational levels. In this context, qualitative research methods can be particularly effective in order to obtain information that cannot be gathered by quantitative research. The success of grounded theory as an inductive, holistic approach has led to an increasing application of grounded theory in the logistics context (Randall and Mello, 2012). The research of this paper is guided by grounded theory in order to investigate transport processes in wholesale and cause-and-effect-relationships on transport performance (Strauss and Corbin, 1998). First, given the lack of literature on transport in wholesale, grounded theory is chosen in order to define transport processes and its particularities in wholesale iteratively. Second, the objective of the present study is to explore cause-and-effect relationships on transport performance within a holistic view. Thus, the application of grounded theory is useful in order to show how individuals operate in the whole and to reveal complex phenomena that have an impact on transport performance. On the one hand, multiple factors influencing transport efficiency have to be explored and on the other hand, transport effectiveness is investigated based on how customers value logistics services. Mello and Flint (2009, p. 114) emphasize that grounded theory is suitable for investigations of customer perceptions on logistics services. Finally, grounded theory is chosen, because it is stated to be appropriate "to create a holistic understanding of phenomena" and "to address behavioral dimensions at the individual, organizational, and inter-organizational level" (Randall and Mello, 2012, p. 864, p. 867). Grounded theory is in close consonant with its philosophical foundation named critical realism. Latter assumes that underlying causal mechanisms are necessary to generate causal-and-effect events. Therefore, an alternative approach for the present paper could have been to view grounded theory through a critical realist frame (Oliver, 2012).

Originally, grounded theory was developed by Barney G. Glaser and Anselm L. Strauss in 1967 in response to criticism regarding qualitative research and in order to improve qualitative research (Glaser and Strauss, 1967). Starting from the initial interpretation of grounded theory, there are different variations of the method now. Grounded theory methodology as further developed by Strauss and Corbin (1998) guides all aspects of this research. In logistics, most researchers refer to Strauss and Corbin (Mello and Flint 2009). Strauss and Corbin (1998) introduced a coding paradigm where coding is central whereby one codes for categories and afterwards breaks them down into subcategories. Grounded theory is based on an iterative research procedure. Hence, grounded theory is a systematic qualitative approach in order to analyze field data by applying a process of constant comparative analysis. As a result, emergent theory is continuously changed, adapted and developed. Strauss and Corbin (1998, p. 15) define a theory as a "set of well-developed concepts related through statements of relationships, which together constitute an integrated framework that can be used to explain or predict phenomena".

Interview participants are sought based on theoretical sampling guidelines. Theoretical sampling is a process of collecting, testing and validating of emergent concepts and relationships during the research process with the objective to develop theory (Strauss and Corbin, 1998). Data collection includes eight interviews, on-site visits in warehouses and transport fleets with view on and explanations of operational processes, co-driving in transport as well as scientific and practical document analysis. In order to obtain rich interview data, eight in-depth interviews with general/owner managers and/or transport leaders from German wholesaling companies are conducted that range between ninety minutes and two hours. The interviews took place at the respective wholesaler's place in various regions in Germany. Seven wholesaling companies are medium-sized companies and one is a large firm. The wholesaling companies are specialized in production related trading for sanitary, heating products and partly for steel goods. In two companies, the interview was executed with transport leaders, in two with general/owner manager and in four with both, general manager and transport leader. After transcription of the interviews, data analysis is conducted using open, axial and selective coding procedures (Corbin and Strauss, 1998). This approach comprises comparing, analyzing in detail and combining themes into categories. In this context, selective coding is essential within grounded theory because the integration of a core category leads to a higher conceptual level. Theoretical coding is conducted by each author independently following the coding techniques and under the use of MAXQDA software. Then, different coders compare their results in order to control for an intrusion of bias. Within continuous interrelation between sampling, data collection and analysis, we focus on analytical ability and theoretical sensitivity in order to recognize data that have pertinent meaning to the emerging theory. In the context of this incremental, iterative process of collecting and analyzing data in grounded theory, the data collection and analysis constantly evolve over time and themes are modified accordingly. After eight interviews theoretical saturation is attained because no additional information is yielded. Finally, an overall theoretical explanatory scheme showing transport processes as well as cause-and-effect relationships can be drawn.

4. RESULTS

The aim of this study is to take a holistic view on transport performance in wholesale. To this purpose, first of all an overview on transport in wholesale is provided. Subsequently, cause-and-effect relationships on transport performance are presented.

4.1. Holistic view on transport in wholesale

To get a holistic view on transport in wholesale and its particularities compared to transport management in other companies, Figure 4.1 (below) shows a process framework which is elaborated and validated within an iterative process during the interviews based on grounded theory. The process framework contains the main ideas of Porters value chain (Porter, 2004). The entire operational process from order taking to goods delivery is presented with its multiple interfaces both within the wholesale company as well as with customers and suppliers. Good flows (in green) and information flows (in orange) are distinguished in order to highlight the dependencies of information flows on derived good flows. Figure 4.1 shows three different process levels in wholesale companies: management processes, core business processes (procurement, sales, warehouse and transport) and support processes (financing, controlling, human resource, and material management). As focus of this study, the core business process transport is shown in detail: transport planning and transport execution. Transport execution is further divided into loading, driving, unloading and fulfilling services. Those activities can be either fulfilled with the own fleet or by logistics service providers.

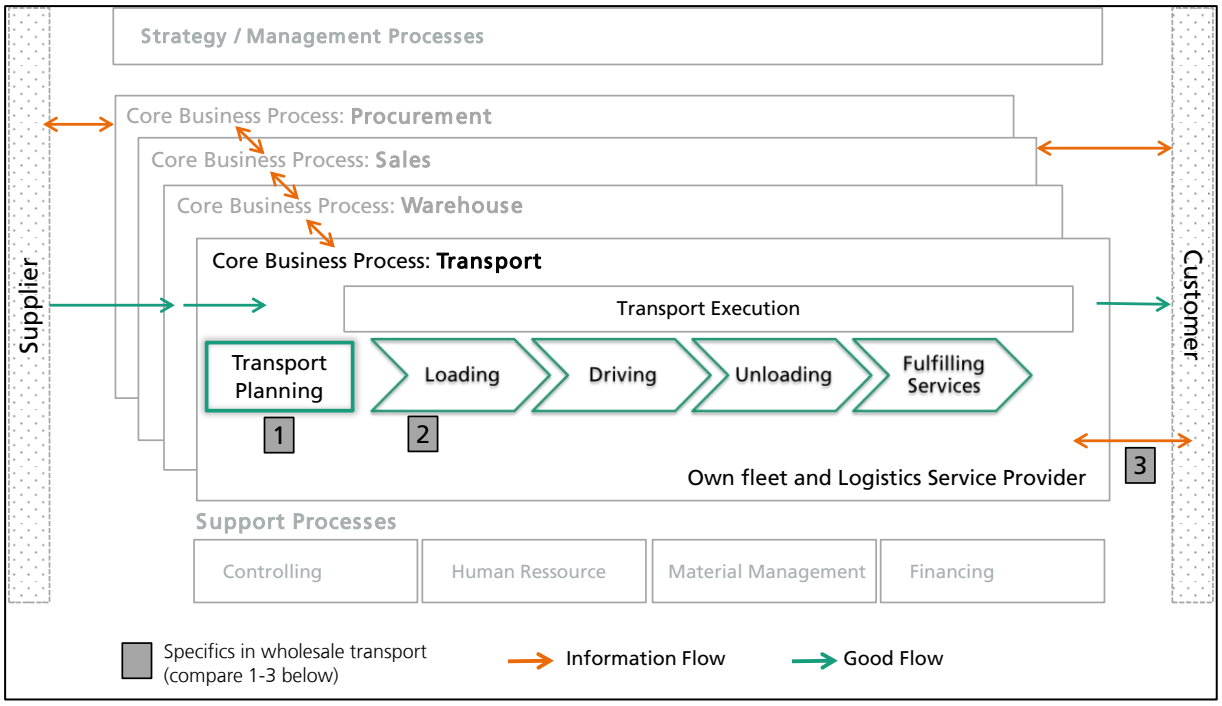

Figure 4.1 Holistic view on transport in wholesale (Own research)

The interviews reveal some specifics in wholesale transport:

1. Within transport planning, transport managers assign customers to determined distribution areas. Especially customers in peripheral distribution areas are often manually assigned to one of the determined tours.
2. Most drivers in wholesale have specific customer knowledge and a long-term customer relationship. Therefore, before loading, they often reschedule tours within the distribution areas by themselves according to customer needs.
3. Due to the long-term relationship between drivers and most of the customers, customers prefer always having the same driver.

Different roles are necessary to fulfill the transport process on different strategic levels. The main task of the transport manager is to plan the operative transport processes and to ensure that transport execution runs smoothly. Furthermore, his responsibilities include vehicle-specific topics. In smaller companies often only one person is responsible for warehouse and transport. Supporting processes such as human resource management is either fully taken over by the respective departments or in close consultation with the transport leader. Strategic issues (e.g. vehicle procurement) are the responsibility of general managers. An important management process in accordance with sales and transport is the development of transports for new sales areas. In contrast to logistics companies, this is not done in terms of efficiency but with respect to new customer development. The task assignment can vary depending on the size of the company. In addition, the organizational structure of such medium-sized companies is not always rigid. Transport management of wholesale includes the management of the internal fleet as well as external transport providers. As a core competence, transport management is not fully outsourced by any interviewed company. Though, the majority of the interviewed companies have outsourced small packaged services in order to better handle supply peaks.

4.2. Cause-And-Effects on Transport Performance

Transport performance in wholesale depends on effectiveness and efficiency in performing transport activities. Based on effect observations, causes of inefficiencies and ineffectiveness in wholesale transport have been investigated. The reasons for performance problems with the contractually-agreed transport work task may arise either by internally chosen resources or by environmental factors (PESTEL) as shown in Table 4.1. Problems within transport resources and operations planning such as consolidation problems, wrong choice of transportation mode etc. do affect the entire performance. In addition, various problems such as not ecological driving etc. do have an impact on operation efficiency. Partly those problems do have an influence on effectiveness; this means the degree to which the performance from the point of view of customer's is fulfilled. The perception of effectiveness depends on how incentives within a supply chain are set.

Table 4.1: Analysis framework to evaluate transport performance (Own Research)

Basis of work	**Performance objective**	**Work task activities**	**Environmental factors**
Relationship between service provider & customer: Contractually-agreed transport work tasks	Efficiency	Input: Transport resources and operations planning	**P**olitical **E**conomic **S**ociological **T**echnological **E**cological **L**egal
	Efficiency	Operation: Freight transport execution	
	Effectiveness	Output: Degree of fulfillment of contractually agreed transport work task	

Subsequently, cause-and-effects on transport performance will be presented starting with transport efficiency.

4.2.1. Cause-and-effects on transport efficiency

Transport efficiency in wholesale shows how economical resources are utilized in order to achieve customer requirements. In the following, information inefficiencies with effect on transport efficiency are shown in an Ishikawa diagram. During the interviews, it becomes evident that most of the inefficiencies result from problems in the flow and transfer of information in wholesaling companies which negatively impact transport execution. Therefore we focus on problems with regard to the information flow. Consequently, errors in information reception, exchange and processing appear within the information flow. This results in resource inefficiencies and sometimes also customer dissatisfaction if problems are not recognized before or service level agreements cannot be met. The illustrated supply chain information flow in Figure 4.2 contains the following information flows: ordering information taken from customers by sales, information transfers between sales and logistics, information flows in warehouse that is related to good flows, information flows within the transport department with regard to transport scheduling and preparation of cargo documents and finally information flows from customer to transport and sales after delivery of products.

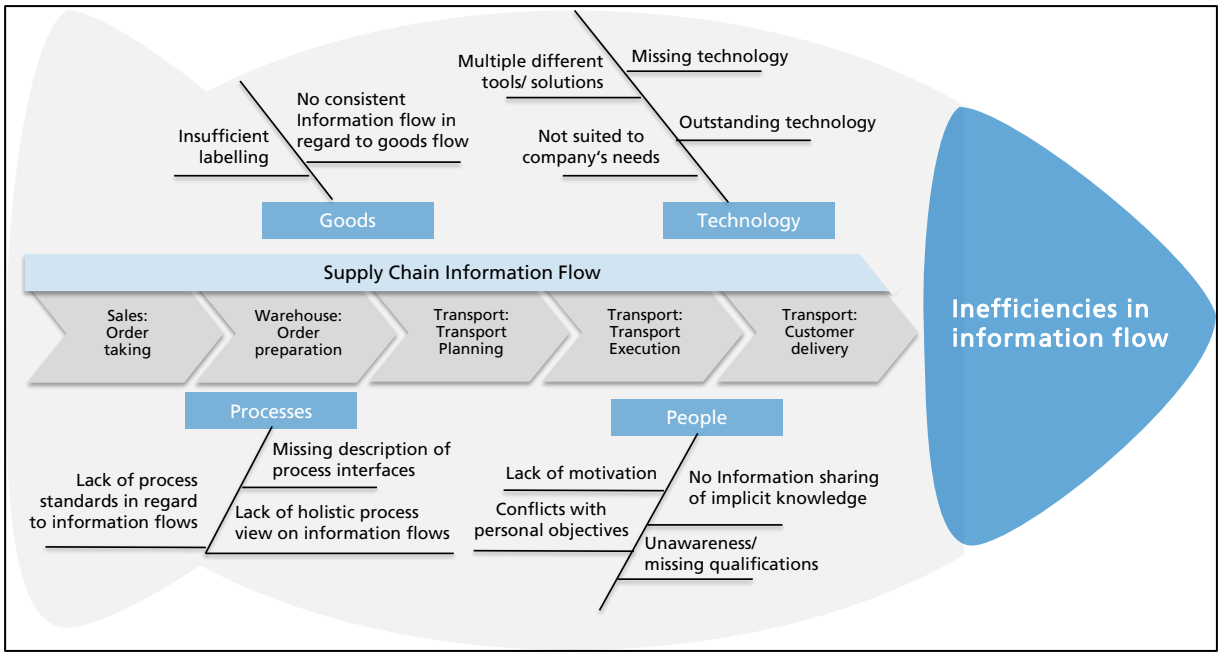

Figure 4.2 Inefficient information flows with impact on transport (following Ishikawa, 1985)

Subsequently, different root causes of information inefficiencies throughout the supply chain are discussed. Inefficiencies in the information flow linked to people, processes, technology and goods that recurrently appear in all companies are presented.

Sales: order taking

The sales department takes orders, acts as a single point of contact for the customer and agrees on logistics service levels with regard to transport. Thus, there are information flows with the customer before, during and sometimes after the provision of services. In this context, information flows ex-ante to ordering may have the following errors: wrong or insufficient information on agreed time, product and place. For instance often new residential areas under construction do not have an address yet or the exact place is not written down accurately enough. As a consequence, sales cannot provide sufficient information to the transport department so that the driver often searches for the right place or has to call the construction site management for directions. Accordingly, the sales department does not have sufficient procedural requirements of how to take orders and information cannot be taken properly. Furthermore, some instructions are not transmitted correctly or in time to logistics. In addition, the sales department frequently makes agreements with customers regarding service levels in transport without further consultation with the transport department. At worst, these service levels cannot be fulfilled by the transport department. Furthermore, the sales department is measured by its customer turnovers. Akyuz and Erkan (2010) state that trade-offs in performance metrics within companies appear due to a lack of compatibility and a failure of transversal metrics.

Warehouse: order preparation

The warehouse department receives information from sales concerning customer orders and has to prepare it for dispatch. Typical errors occur in handling of goods within good flows with regard to the product, its quantity or the quality of the product (e.g. damages). Furthermore, problems in information flows such as wrong labelling arise. Causes of problems in operational good flows are as follows: lack of process standards, negligence of

warehouse staff, problems with regard to missing/outstanding IT support or problems in application of IT software.

Transport: transport planning

Problems in transport scheduling occur because not all information is available for planning. Transport leaders schedule either manually or semi-automatically with a route planning software. In most of the companies, transport planning processes are performed manually with Excel files. Transport scheduling is done for fixed routes. In case of automated planning processes, areas that are far off need to be attached to those tours which fit best in terms of delivery times etc. Customers in those areas receive goods from different drivers. In most companies, scheduling is done before closing of online shops because of working hours. As a consequence, due to late opening hours of online shops, scheduling requires later adaptions. In case of application of route planning software, customer restrictions that are known by transport leaders such as specific time constraints require later adaption of automatically planned tours. In addition, further information on vehicles and staff such as maintenances or vacation lists of drivers are separately managed in additional Excel files or software tools which have to be considered as well while planning transport execution. Furthermore, usually adequate product-related master data provided by the manufacturer such as weight, volume of products etc., are partially or completely missing for efficient scheduling of transports. Finally, transport scheduling cannot be finished by transport leaders because later adjustments on the final route are done by the driver on the basis of his implicit knowledge on customer needs. Therefore, continuous loops on transport planning processes are necessary.

Transport: transport execution

The three most important resources which are used in transport execution are drivers, vehicles and fuel. Drivers usually represent the largest cost factor (Sternberg *et al*., 2012). Companies should better focus on driver's core competencies which mean that the driver is most productive when driving. Loading activities accounts for 15 to 20% of working time in the interviewed companies which is conform to other studies in transport (Sternberg, *et al*. 2014). Therefore, it is questionable whether drivers should do loading activities themselves. Finally, the performance of transport execution in wholesale as the last link in the supply chain is only as good as the entire process performance.

Transport: customer delivery

In wholesale, customers and drivers do have a long-term relationship and drivers usually do have specific customer knowledge. Therefore, drivers often reschedule tours due to their implicit knowhow regarding customer habits (e.g. break times). This implicit knowledge of the driver must be converted in explicit knowledge. Therefore, drivers should transfer knowledge regarding specific customer preferences with regard to delivery. According to previous studies, benefits due to customer knowledge sharing are proven (Stank *et al*., 1996).
On the one hand, inefficiencies in wholesale transport are cost-intensive but on the other hand these inefficiencies can also have a negative impact on transport effectiveness.

4.2.2. Cause-and-effects on transport effectiveness

Transport effectiveness in wholesale addresses the question of how the requirements of customers are met. Efficiency and effectiveness are pursued at the same time whereas effectiveness is of higher emphasis for the interviewed companies. With the objective of categorizing these customer requirements, the Kano model is applied in order to show the relationship between customer satisfaction and transport performance. The Kano model divides customer requirements in three categories: basic needs, performance needs and

delighters (Kano *et al*., 1984). Basic needs are primary criteria for consumer satisfaction that are taken as evident by the consumer. In case of non-fulfilment of these criteria, customers are extremely dissatisfied but their fulfilment does not automatically lead to customers' satisfaction. In this context, customers expect the right product in the right quality at the right place at the right time to the right costs. Any defect in any of the aspects mentioned before results in extremely dissatisfied customers. In general performance needs are explicitly mentioned by the customers. Consequently, customers are dissatisfied if they are missing and their level of fulfilment impacts customer satisfaction. With regard to transport in wholesale, for example customized smaller product assortments were recognized as performance needs. Delighters are latent. Therefore, these value attributes are neither explicitly demanded nor expected. However, customers are delighted in case of strong fulfillment. Individual services such as additional handling of goods were recognized as delighters.

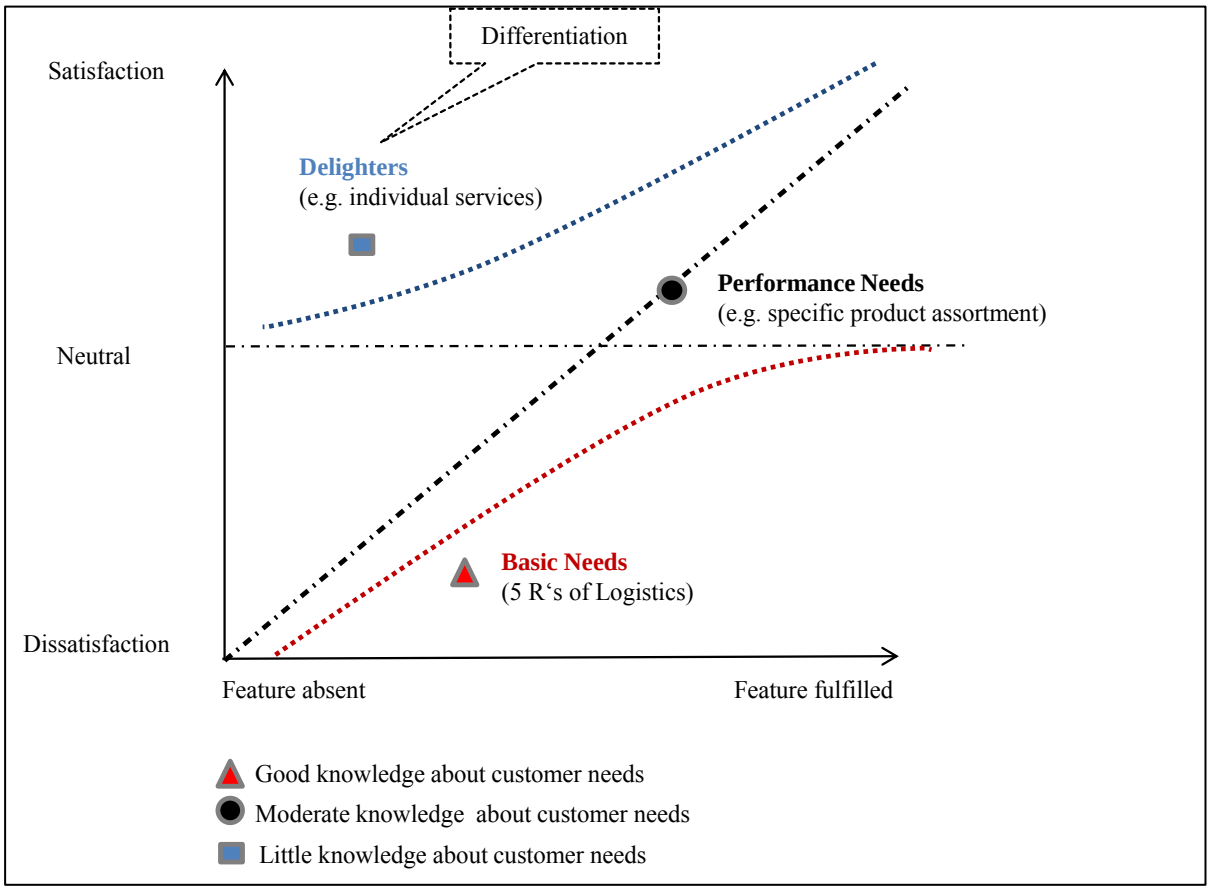

Figure 4.3: Customer satisfaction with logistics from wholesaler's viewpoint (own research)

Figure 4.3 shows different degrees of fulfilment of transport service features from basic needs to delighters. The overall answers of the interviews regarding customer satisfaction are presented in Figure 4.3 for the categories fulfillment and knowledge about customer perception. Only the fulfillment of delighters can lead to differentiation from the competition.

Insufficient fulfillment of transport effectiveness

Interview results show that often, customer's basic needs cannot be fulfilled to the satisfaction of the customers. Ensuring a smooth functioning of the basic logistical requirements is especially important given the background that customers ordering behavior has changed significantly with opening of online shops. Short-term order behavior has a strong impact on logistics with regard to greater flexibility and leads to shorter planning cycles. During the

interviews, it became evident, that from a wholesaler's point of view, supply reliability is the most important criterion for customers within the transport process. Given the background of later ordering, wholesalers do have increasing problems in terms of responsiveness. Even small craftsmen outsource their logistics and order relatively small quantities within ever shorter timescales. Hence, there is an increasing demand for logistics concepts such as Just in Time not only for JIT deliveries to construction sites. Those customer requirements are difficult to fulfill with regard to a certain level of logistics including transport efficiency. Consequently, wholesaling companies should be closer to customers from a logistical point of view. In comparison, competitors do have smaller warehouses in urban agglomeration close to customers and thus, can be more flexible in terms of transport logistics. Currently, the adaptation of logistics to novel delivery concepts poses challenges to wholesalers both with regard to fulfillment of service levels and concerning the efficiency of their own processes. One wholesaler describes it as "service overkill".

Insufficient knowledge about customer's perception on transport effectiveness

Transport effectiveness is seldomly considered. Wholesalers state that they do not know if their customers are satisfied with logistics. Some general managers refer to the sales staff. In case of complaints, customers contact the wholesaling company directly. Consequently, customers are satisfied if the wholesaler does not get complaints. Only one company has led a present customer satisfaction survey. Therefore, optimizations are mostly efficiency driven and lack a customer orientation. In contrast, wholesale companies improve efficiency in logistics to the detriment of transport effectiveness. As part of efforts to increase transport efficiency, scheduling based on a tour optimization program is introduced in some companies in order to better schedule transports. As a consequence, drivers of those companies do not any longer have fixed tours and they are not responsible anymore for the same customers. According to the interview statements, customers have taken it badly because they prefer to have fixed drivers and also fixed delivery times. The importance of drivers has further declined due to new delivery concepts to construction sites where drivers often do not have contact with customers anymore. Nonetheless, for many customers, it is still important to continuously have the same logistics contact person. Although prior studies highlighted the importance of frontline employees in logistics and physical distribution, recent studies stressed the relevance of drivers within physical distribution. Thus, drivers as other customer contact employees do have an impact on customers purchase behavior (Bode *et al*., 2011).

Missing strategic perspective with regard to transport effectiveness

Transport performance regarding transport effectiveness is not recorded regularly and systematically. Due to high competition and customer's power, a differentiation through logistics becomes more and more important. Therefore, collaborative planning with customers could lead to more efficient processes and these gains could be shared in the supply chain. Customer specific differences in transport logistics depending on customer's importance are not yet taken into account. However, in order to differentiate wholesale companies need to fulfill performance needs to a higher level and have to find attractive value elements in order to delight customers. Most of the interviewed wholesale companies think about possible cost reduction strategies such as further outsourcing of parcel shipments in order to make transport more efficient. However, the majority of the interviewed companies does not intend to fully outsource transport. But currently wholesalers perceive new customer demands on logistics as a burden rather than a chance. Thus, logistics including transport are not in wholesaler's strategic focus. Possible differentiation strategies are not taken into consideration even if this would lead to customer loyalty. Hence, a logistics differentiation strategy is necessary in order to be effective and satisfy the customer on a long-term perspective.

4.2.3. Performance drivers on an operational, tactical and strategic level

Transport inefficiencies and non-fulfillment of transport effectiveness do have a negative impact on transport performance. Table 4.2 shows correcting actions at operational, tactical and strategic levels in order to better perform in transport.

Table 4.2: Performance drivers at an operational, tactical and strategic level

Correcting actions	Transport Efficiency	Transport Effectiveness
Operational level	Documentation and standardization of operational processes and clearly assigned tasks in logistics	Clear interfaces between transport and sales department with regard to customer communication
Tactical level	Consistent information flow from order taking to delivery of products	Conjoint planning processes with customers
	Regular controlling of transport performance	Customer satisfaction surveys as part of performance measurement
Strategic level	Establishment of a consistent performance measurement of the entire process based on strategy	Reconsidering the role of logistics in corporate strategy

For the majority of general or owner managers, logistics and thereby transport logistics represent a reactive, operational process. Transport is often seen as the extended arm of sales. Most operational process errors result from a lack of documented and standardized processes. Furthermore, employees in warehouse and transport do not sufficiently know how to use IT software. Interfaces between sales and logistics are not clearly addressed by management. During the interviews, some general managers searched for documents in order to provide further information and figures on transport, but these were not readily available for most. In their opinion, the transport department must meet customer satisfaction at the lowest possible costs. In most companies, managers do not sufficiently know to which extend resources in transport are used. Controlling in transport is rarely done even if adequate IT software is present. Knowledge regarding the operation of the systems is mostly absent because it has not been used before. In middle-term, wholesalers need to build up consistent information flows in order to reduce information inefficiencies within processes. Prior research has proven efficiency potentials through support of information technology (Sternberg et al., 2014). Furthermore, customers should be integrated in planning processes in order to build-up a win-win situation which leads to more efficient and more effective transport processes. Activity based costing is not yet implemented in order to outline customers impact on logistics costs. Therefore, transport services are equal for all customers and costs are not allocated. In addition, regular customer satisfaction surveys should be included in controlling of transport performance. All general managers intend to have indicators for measuring transport performance. Currently, incentive systems to increase the efficient use of resources are not yet implemented in most companies. If any there are only incentive schemes for all employees without taking into account the performance of the individual employee. Furthermore, only one company conducts annual talks with drivers. In most of the other companies, this is not even done with transport leaders. With the objective to improve transport performance, wholesaling companies need to establish not only transport performance measurement but a company or even supply chain wide performance measurement system based on strategy.

Finally, companies have to reconsider the role of logistics in corporate strategy in order to build up long-term competitive advantages. There is a trade-off between transport efficiency and transport effectiveness. However, excellent logistics helps to gain competitive advantages (Tracey, 2004). Therefore, companies should not only focus on short term efficiency, but consider long-term advantages due to a customer oriented logistics strategy.

5. CONCLUSION, LIMITATIONS AND FURTHER RESEARCH

In a highly competitive market environment, wholesalers face current challenges in transport logistics due to the fact that customer demands on the one hand and transportation costs on the other hand are constantly increasing. For competitive reasons, a holistic investigation on transport performance and its influencing factors needs to be done.

In this paper, we have studied influencing factors on transport performance considering both transport efficiency which means how efficient resources are utilized and transport effectiveness which implies if customer goals are achieved. The contribution of the research presented in this paper is twofold. First, we illustrate transport management processes and activities of wholesaling companies which were not yet examined before. Second, cause-and-effect relationships on wholesale transport performance on operational, tactical and strategic levels are presented. Based on eight in-depth grounded theory interviews, a framework of processes and activities of transport management in wholesale has been illustrated. Transport management in wholesaling companies is indeed considered as a core process but logistics still lacks strategic importance. In this context, main transport management tasks such as controlling are not done. Transport managers only have operational goals with regard to transport execution. Previous literature mainly addresses effects on transport performance. Within this contribution, main causes with effect on transport performance are elaborated. In terms of transport effectiveness, currently, basic requirements cannot be fulfilled to customer's expectations and there is a lack of a holistic customer-oriented logistics strategy based on company's focus. Regarding efficiency, wholesalers have difficulties in information flows. There is a current need to develop consistent, accurate information flows. Finally, wholesalers do not sufficiently know customer needs and do not address transport performance by continuously monitoring performance features. The achieved results provide some managerial implications and can be used to reconsider logistics in wholesale within a holistic view. Given the background that transport, as the last link in the supply chain, only reflects the entire logistics performance, transport should not be subject to individual local consideration. Thus, the proposed findings allow companies to improve both, transport efficiency and transport effectiveness. The results provide implications for corrective actions at different levels. For this purpose, wholesalers need to be aware of further strategic focus in terms of efficiency and effectiveness. Differentiation in transport logistics might help wholesaling companies to obtain competitive advantages.

However, our contribution shows some limitations. First, our research focuses on production-related wholesaling companies in Germany. Nevertheless, the wholesale industry is one of the most representatives in Europe in terms of turnover and employees. Second only wholesaling companies were interviewed. In order to get a broader view on transport performance it is necessary to also focus on customers. Besides the limitations, there are some issues which constitute opportunities for future research. This paper has focused on production-related wholesale. Findings might be different for other wholesale sectors. Furthermore, it would be of scientific value to validate and extent the acquired findings. Therefore, a broad empirical basis seems necessary. Finally, an extended view on cause-and-effects on transport performance in the other sectors could be meaningful.

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APPENDIX

Interview Guide

1. What are your tasks in transport management?
2. How does the interface between transport and other departments work?

External requirements to the transport department

3. What are (your client's) external requirements to wholesale?
5. How is the wholesale transport department set up to meet these requirements?
6. How satisfied are your clients currently with wholesale transport services?

Internal requirements (management, other departments)

7. Which internal requirements does the transport department have to meet?
8. How do you measure the transport performance?

Wholesale transport performance

9. Which factors do you think have a positive impact on transport performance?
10. Which factors do you think have a negative impact on transport performance?
11. How do you use your knowledge about these factors to improve transport performance?

Pollution or poor competitiveness - Short sea shipping between the devil and the deep blue sea?

Early impacts of the new SECA regime for maritime transport

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ABSTRACT

Purpose

The purpose of this paper is to review anticipated and early impacts of the Marpol SECA regime for the reduction of sulphur emissions from maritime transport in North Europe.

Design/methodology/approach

The data supporting this analysis stems partly from the scientific literature, statistical sources and industry information sources. The main approach is therefore a literature review.

Findings

Seven main categories of anticipated impacts were identified; that there will be higher operating costs, higher freight rates, loss of short sea market shares, loss of competitiveness for importing and exporting industries, and that most operators will switch to low sulphur fuels and some operators will choose to avoid SECA areas, and, finally, that investments in LNG propelled newbuildings/retrofits and scrubber systems will increase. Anticipated increases in fuel costs have, to a large extent, been counteracted by the general fall in crude oil prices.

Research limitations/implications (if applicable)

This paper is written just 2-3 months after the new sulphur regime came into force. Obviously some impacts will only be observable in the longer run.

Practical implications (if applicable)

There is no evidence this far that the new regime will move cargo from sea to land transport.

Social implications (if applicable)

This new regime may be seen as a way of internalizing external effects of sulphur emissions from shipping.

Original/value

This review should be highly interesting both to industry actors and to government bodies dealing with regulations and incentives pertaining to freight transport.

Keywords: Maritime transport; Sulphur emissions; SECA; Marpol; Short Sea Shipping

1. INTRODUCTION

Shipping has generally been regarded the green mode of transport, although this "truth" does not apply to all settings and over all environmental dimensions (Hjelle, 2010, Hjelle, 2014, Hjelle and Fridell, 2012). A much focused problem has been the use of high sulphur heavy fuel oils which means that exhaust gases, if they remain untreated, are harmful to human health and the general environment. Lately the main regulatory instrument for dealing with emissions to air from maritime transport, the MARPOL Annex VI convention, has been amended to include sulphur emissions. This convention means that sulphur emissions control areas (SECAs) have been introduced in some parts of the world. In this article we assess the impacts of such a regime in the north European case.

Firstly we briefly introduce the background and development of this new regulatory regime in Section 2. Then we review the expected impacts identified in reports, scientific articles and the shipping media prior to the new regime (Section 3). Further, the early evidence on the impacts that actually has materialized and which could be identified through various sources are identified (Section 4), before the general impression of the early impacts and potential lessons are summarized in Section 5.

2. BACKGROUND – THE DEVELOPMENT OF REGULATIONS OF THE SULPHUR CONTENT OF MARINE FUELS

Reducing sulphur emissions from shipping is expected to reduce the acidity of precipitation in residential areas – which will have a positive impact on human health, especially for people with respiratory problems (Ljungberg et al., 2013). The climatic impact of reduced sulphur emissions is rather uncertain due to many counteracting impacts that are hard to quantify ex ante. Less sulphur will mean less black carbon, which will help reduce global warming. On the other side, producing low sulphur fuels requires more energy than the production of traditional heavy fuel oils. Adding to this is the likely modal shift from sea to land-based modes if complying with the new SECA regulations means higher prices for sea transport (Magnus et al., 2014).

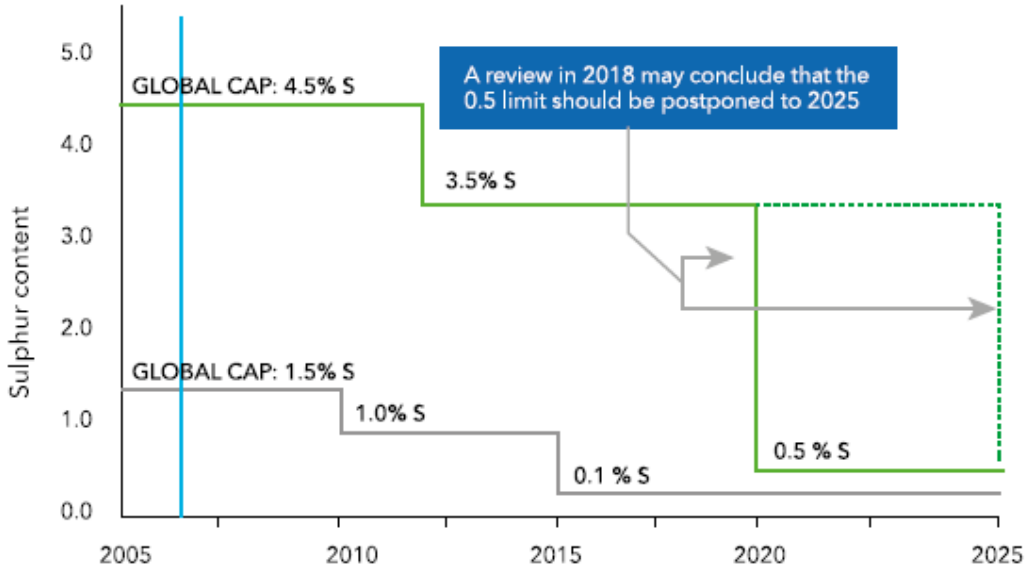

Figure 1.1 Marpol Annex VI fuel sulphur content limits (DNV-GL, 2014)

The SECA regulations are based on the Marpol Convention ("The International Convention for the Prevention of Pollution from Ships" of the IMO (The International Maritime Organization), which is the UN body dealing with regulation of maritime transport. The Marpol Convention was created in 1973, but has been amended several times since then. The regulation of emissions to air was introduced into the Marpol regime when the Annex VI was adopted in 1997. These regulations came into force in 2005, e.g. introducing a global cap on the sulphur content of marine fuels of 4.5 percent (by volume). This was not a very ambitious regulations to begin with, but a stepwise tightening of the regulation was also agreed upon, gradually reducing the sulphur content of fuels at specific future dates (Figure 1.1).

On top of this an even more ambitious approach was introduced for specific geographical areas – the so-called Sulphur Emission Control Areas (SECAs). In 2006 the Baltic Sea was defined as a SECA, the following year, the North Sea and the English Channel followed on. Later further areas along the East and West coast of North America and the US Caribbean have also been added to the list of SECAs. By 1 July 2010 the allowed sulphur content of the fuel within the SECAs was reduced to 1.0 percent, and by 1 January 2015 this was further reduced to 0.1 percent. The latter reduction from 1.0 percent to 0.1 percent is much more challenging for the operators, and complying with this is far more costly than the earlier steps taken.

Within the EU the IMO Marpol Annex VI regulations are implemented into an EU directive (EC, 2012), which also goes beyond the scope of the Marpol text when it comes to stricter regimes to be implemented outside the SECA areas in 2018 and 2020 (Cullinane and Bergqvist, 2014). Some 2 200 vessels are operating all the time within the European SECA areas, and more than 10 000 more will operate within European SECAs part of the time (Haram, 2014). The most recent (2015) tightening of the sulphur regulations were known more than 6 years prior to the implementation. This means that the industry should have had ample time to adapt to the new regime, even considering the length of the order-books for ordering new tonnage or conversions. However, up until the last months before the implementation, some industry actors were still hoping for a deferral or compensating measures to ease the transition.

Over the last years both scholars and industry actors have analysed the potential impacts of the new regulatory regime. In the next section we will review these expectations.

3. REVIEW OF EXPECTED IMPACTS

We have reviewed academic sources through searching for articles addressing the regulation of sulphur emissions from maritime transport in general and the MARPOL and SECA regimes in particular. Our main databases for the scientific literature search have been The Web of Science and Google Scholar, applying the search terms "SECA", "Sulphur Emission Control Areas", ""sulphur emissions" & "maritime transport", - and all of these combined with "impacts". Since this is a new regulatory regime we have limited the search to contributions published between 2010 and 2015. Since the lead-time for academic publishing means that the latest developments could not be found in the scientific literature, we have augmented this with industry sources, partly bespoke reports addressing the issue, and partly for news-articles in relevant maritime media sources like Lloyd's List, IHS Maritime 360 and European short sea information web sites. Again, the same set of search terms has been applied, apart from the combination with "maritime transport", since these sources are focused on this industry only. Applying the industry sources, rather than scientific sources means that there may be a stakeholder bias in the way the problem area is treated. We have been very much aware of this potential bias, and tried to compensate for this by applying

multiple sources, written from different angles. The articles found through the searching of these sources have been read, and references to expected (Section 3) or revealed (Section 4) impacts of the new regulatory regime have been identified. The searches of the databases have been conducted between February and May 2015. Based on this literature review, we have identified 7 categories of expected impacts from the SECA regulations, which are described below.

3.1. Higher operating costs mean higher freight rates

Most operators expected to switch to low sulphur marine gasoil (LSMGO) after the new regulations were implemented (Ljungberg et al., 2013, Magnus et al., 2014). The prices of LSMGO were expected to increase by 5 to 20 percent (Ljungberg et al., 2013) in the short run. Compared to heavy fuel oil (HFO), which was the most used fuel before the regulations, this represents an expected fuel price increase of 50 to 75 percent. For a typical size (1000 TEU) container vessel this was expected to represent an increase in total costs of 15-20% (Haram, 2014). According to a report by Drewry Maritime Advisors, transport costs on transatlantic voyages were expected to rise by USD 29 (US East coast) to USD 49 (US Gulf coast) per TEU. Equivalently, Asia to Europe voyages was expected to rise by USD 100 to USD 120 per TEU. This represents an increase in BAF (Bunker Adjustment Factor) of 20% (Leander, 2014). Most operators were planning to fully reflect the increasing fuel prices in their freight rates (Magnus et al., 2014, Newton, 2015).

3.2. The port industry expects limited impacts

Port authorities interviewed in Magnus (2014) had not made any quantitative assessments of potential impacts of the new regime. When asked about potential compensating increases in port dues following a potential drop in cargo volumes, most responses were that this depended on what other actors chose to do.

3.3. Fear of lost market shares for short sea shipping

Short sea operators have expressed concern that increased freight rates would cause a loss of market shares to road transport (Magnus et al., 2014). This expectation is confirmed also in other analyses (Ljungberg et al., 2013, Holmgren et al., 2014). However, some markets are more protected against competition from land based modes than others. One example would be industries that have cargo volumes that benefit from the substantial economies of scale offered e.g. by chemical tankers, or who have cargo that would largely be "out of gage" for land based modes. Here there is really no alternative to sea transport, and customers will just have to accept that increased (fuel) costs imposed by the SECA regime will be fully reflected in the freight rates. In the longer run, a lasting change in fuel prices will generally be expected to have impacts on route choice, service frequency, transport velocity, cargo consolidation and mode choice (Ljungberg et al., 2013). European ship owners have warned against potential consequences like the closure of short sea services or a reduction of route frequencies (ESSF 2013) and have warned against a massive increase in road freight transport across Europe as a consequence of the SECA regime (Porter, 2010).

3.4. Exporting and importing industries within SECA areas may lose competitiveness

Magnus concludes that Norwegian export industries probably will get an increased transport cost of 4-6 billion NOK resulting from this. Some of this might be passed on to customers, but in most industries this was only expected to reduce the competitiveness of the exporters in the world markets where small and medium sized actors will have to adapt as price-takers.

Similar conclusions are drawn for the export of paper from Northern Sweden to England and the BeNeLux countries (Ljungberg et al., 2013), where transport costs are estimated to increase by 10 percent. A case study (op. cit.) with steel exports from Mid-Sweden to Denmark resulted in estimated price increases of 3 percent. Here simulations that included changes of transport routes and mode choice were also taken into account.

Norwegian import industries, especially those who are in the local retailing business, will most likely be able to recoup freight rate increases in the consumer markets, but for most actors this may also mean lost sales, in particular for the ones competing with locally produced commodities.

Some actors may even suffer a double impact from the SECA regulations, because they are reliant on sea transport for both importing raw materials and for exporting finished products. A key example here is the Norwegian aluminium industry. Typically they import raw materials (alumina) from abroad with bulk ships, process it in Norway, and export finished products by bulk ships, general cargo ships and container vessels. Competing actors, e.g. located in Asia will not be subjected to such extra costs. This means that actors within the SECA-regions will lose competitiveness from the new regulatory regime.

3.5. Operator technology choices may be different in the short and long run

Most operators interviewed in (Magnus et al., 2014) reported that in the short term, there was really no other choice but to switch to low sulphur fuel. Other technology options (conversions, newbuildings) were regarded too costly, but a few actors had already ordered LNG ships or installed scrubbers[1]. These alternatives will mainly be considered when a renewal of the fleet is considered for other reasons as well, e.g. market or technical obsolescence. This anticipation is also confirmed by the Swedish study conducted by (Ljungberg et al., 2013). When asked about which technology options Norwegian ship owners considered in 2014 (Haram, 2014), all of them considered switching to LSMGO, 15 percent considered newbuildings with LNG, 12 percent upgrading to LNG, 18 percent installing scrubber and 15 percent moving ships to other regions. In the Lloyd's List 2014 Sulphur Survey 48 percent of the respondents considered distillate fuels to be the most suitable option for meeting the SECA regulations, 22 percent said LNG and 17 percent scrubber systems (Lloyd's List, 2014). In a late 2014 survey conducted among the members of the European Community Shipowners' Association (ECSA), 97% of the respondents said they would be switching to low-sulphur fuel (Newton, 2015).

However, many operators (e.g Danish shortsea operator DFDS) have established a policy to fit scrubber systems to the newer part of their fleet, but expecting the older part to be replaced by LNG propelled vessels when their economic life ends (Eason, 2014c, Newton, 2015).

The uncertainty and differences with respect to choices of technologies can be understood by examining ex ante life cycle cost assessments (Bengtsson et al., 2014), which illustrates how many uncertain factors would influence the bottom line. Estimated investment costs for new technology, maintenance costs and fuel costs are too influenced by uncertainties too draw any firm conclusions. Even when calculating the full costs and benefits of different technology options from a societal point of view, it seems that estimates of the price spread between fuel types will be a determining factor (Jiang et al., 2014) for the choice of technology (DNV-GL, 2014). Investments in ships and even retrofits are long term decisions under uncertainty.

Table 3.1 Overview of expected impacts from the new SECA regulations (own compilation)

[1] The term "scrubbers" is used to describe a group of air pollution devices installed for the after-treatment of exhaust gases, in this setting to remove sulphur stemming from the use of high sulphur fuels.

#	Expected impact	Description
1	Higher operating costs	Fuel costs represent a considerable component in shipping operating costs, especially for vessels with a high operating speed. Increased fuel costs are expected due to the price spread between traditional fuels (HFO, IFO, MGO) and low sulphur fuel (LSMGO). Higher operating costs may also result from longer sailing routes chosen to avoid SECA areas, and/or higher operating speeds outside the SECA areas to compensate for the longer sailing distances. Higher operating costs may also stem from the operation and maintenance of scrubber systems.
2	Higher freight rates	In some sub-markets one could expect that higher operating costs are transferred to customers, especially in captive markets where there are no alternatives to maritime transport.
3	Loss of short sea market shares	In break bulk, container and ro-ro markets there is a fierce competition between short sea shipping services and land-based modes. Higher freight rates resulting from higher operating costs may result in loss of market shares.
4	Loss of competitiveness for exporting and importing industries	Exporting and importing industries with long distances to markets or raw materials, especially those who cannot substitute away from maritime transport will lose competitiveness from higher freight rates.
5	Most operators will switch to low sulphur MGO in the short run	As many alternative technologies (scrubber, LNG conversions or newbuildings mainly) represent significant investments and are time-consuming, most operators expect to switch to LSMGO in the short run. Also a real option analysis may support strategic choices of deferring such investments.
6	Some operators may choose to avoid SECA areas despite longer sailing distances	On some legs it may be possible to choose alternative sailing routes which for a longer or shorter part of the journey will be outside the SECA. Typically ships will then slow down inside the SECA and speed up when sailing outside the SECA.
7	Investments in LNG newbuildings, LNG conversions and scrubber systems will increase	Especially when new tonnage is needed anyway, more vessels will be ordered with LNG propulsion systems. Some shipowners will choose conversions of existing tonnage – either to accommodate the use of LNG or to install scrubber systems. A few other alternatives also exist, e.g. the use of Methanol as fuel, already installed by Stena Line on one of their ferries.

Deferring investments e.g. in LNG technology may also be a justifiable strategic choice in such a decision climate (Acciaro, 2014).

3.6. Route choice and operating speed may be affected by the SECAs

An alternative to investments in new technologies or fuels is to alter sailing routes or operating speeds. In Fagerholt et al. (2015) an optimization model is developed for analysing the impacts of increased fuel prizes, e.g. triggered by the new SECA regulations. The model is applied to several European cases, and these examples illustrate that total fuel use and the resulting emissions of greenhouse gases may increase as a result of longer sailing distances chosen to avoid the SECA areas, or from applying higher sailings speeds outside these areas to compensate for the longer sailing distances.

The main driver behind the adaptations is the difference in prices between LSMGO and HFO, and expected impacts on route choice and operating speed will be more outspoken as this spread increases (Doudnikoff and Lacoste, 2014). If impacts on route choice and fuel consumption from increased speeds are limited, then the use of alternative low sulphur fuels will probably not have a major impact on climate change (Chryssakis et al., 2014, Brynolf et al., 2014).

4. EARLY EVIDENCE ON ADAPTATIONS TO THE SECA REGIME

This paper is written only 2-3 months after the tightening of the SECA regime came into force on 1 January 2015. It may seem rather early to log impacts of the new regime at this early stage, but there are a few aspects that may justify a review at this early stage. Firstly, the new regime has been known for more than six years. Although a few actors have hoped for postponements, adjustments or mitigating policies up until now, most of the industry has prepared for the new operating environment for several years already. Secondly, since assets in this business are long-lived, one would expect that recent investments in new tonnage have been made based on knowledge about the new regulatory regime. However, it is also quite clear that the latter element also will contribute to a rather slow adaption to the new regime, as older tonnage normally will remain in operation for several years. Some potential impacts, e.g. related to entirely new routes for cargo, will not happen overnight as they could require new infrastructure or new business partnerships within the supply chains. Adding to this is the fact that the adaptations to such a new regime made by the individual actors, normally will be influenced by what other actors do. It is therefore quite normal that many operators enter the new regime with a "wait and see" approach. The complexity of analysing early impacts is also related to time-lags in the production of statistical evidence. The official statistical data, e.g. pertaining to cargo-flows, will largely not be available at this early stage. This means that the review of early adaptations presented in this section is largely based on news-articles in the shipping media and reports presented by market actors like classification societies and organisations representing the operators and providers of fuel, retrofits and newbuildings.

4.1. Most operators have gone for low sulphur fuel in the short run

In a recent review of announcements made by 70 European shipping companies within deep sea, short sea, passenger, ro-ro, general cargo, bulk carriers and tankers, MEC Intelligence (Pathak, 2015) reports that 55 of the 70 companies have disclosed their compliance strategies publically. 75% of the passenger and ro-ro operators had gone for LSMGO. In the second Lloyd's List Sulphur survey, conducted among shipowners in 2014, 48% reported that they expected to switch to low sulphur distillate fuels. When the same survey was made again in 2015 (after the new regulations), this figure had increased to 62% (Eason, 2015c).

4.2. LNG propulsion is probably regarded an attractive solution for reducing operating costs in the longer run

LNG is cheaper than diesel fuels and while the technology to use the fuel, which has no sulphur content, is costly, the operating costs are lower. This makes it an attractive possibility for some shipowners, particularly those ordering newbuildings for shortsea or dedicated route operations (Eason, 2015e). US gas prices (represented by Henry Hub in Figure 4.1) are definitely lower than alternative fuels, whereas the case for LNG could be made within the SECA areas of Europe where the alternative is LSMGO. As can be seen from Figure 2, fuel prices for all fuels have dropped significantly over the last months, but the prices for MGO and IFO has dropped much more than gas prices. The comparative case for LNG propulsion is therefore weakened if this situation prevails.

4.3. A few operators have chosen to cease operations on certain lines

DFDS and Transfennica are two shortsea operators with vessels operating mainly within the European SECA. Both actors have recently closed off routes, partly with reference to the new costly SECA regime (Eason, 2015e, Brett, 2015). The Transfennica Bilbao-Portsmouth-Zeebrügge service was originally supported by 6.8 million Euro by the Motorways of the Seas / Marco Polo programme of the EU (Porter, 2014). DFDS dropped their Esbjerg (DK)-Harwich(UK) line, and the operator is partly blaming the new fuel regime. Both lines have struggled to make a profit and the new regime may or may not be the straw that breaks the camel's back. According to the operator this has been a contributing factor.

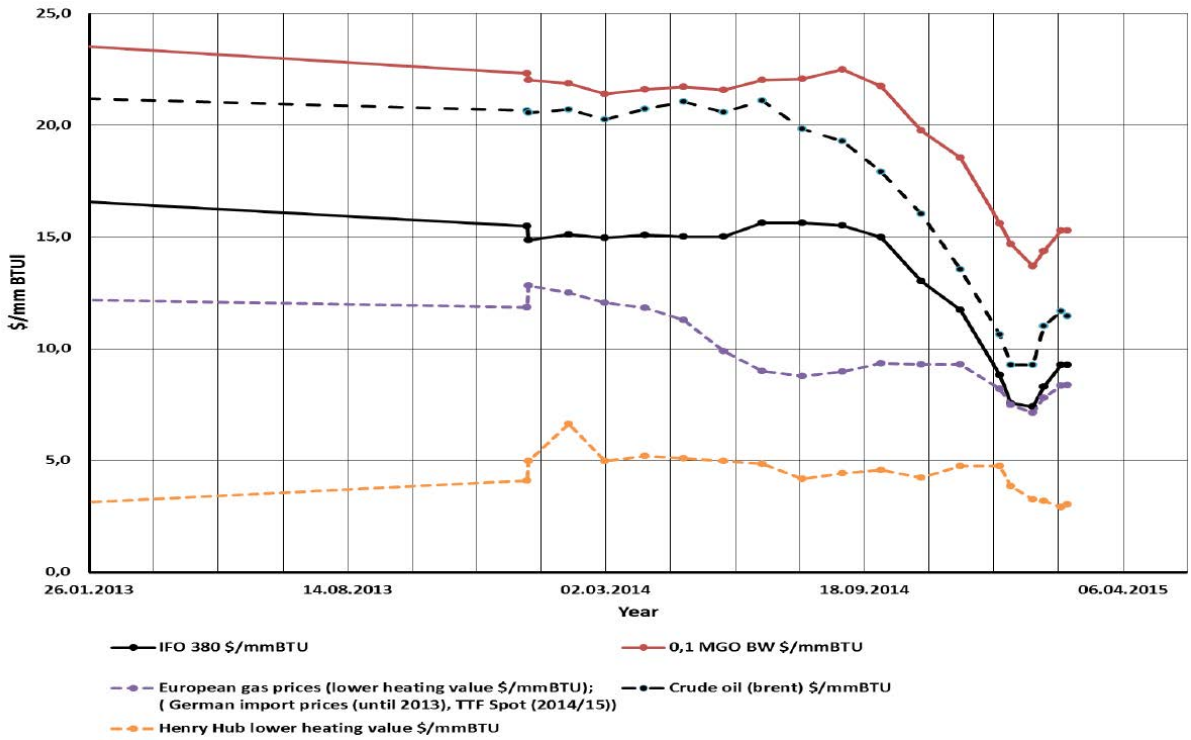

Figure 4.1 Marine fuel prices per mmBTU[2] (DNV-GL, 2015)

[2] mmBTU=million BTU (British Thermal Unit, equivalent to 1055 joules)

4.4. Many operators have announced a new bunker adjustment factor to deal with low sulphur fuels

Despite the drop in crude oil prices, the large price differential between heavy fuel oils and low sulphur diesel oils is still present. This has led to the introduction of a sulphur surcharge (Eason, 2015e) or a general adjustment to the bunker adjustment factor (BAF). Examples of announced increased BAFs due to the use of low sulphur fuels on container lines are on the Asia-Europe trade: Maersk $30/FEU, MSC $15/TEU and CMA CGM $25/TEU (Brett, 2014). However, this does not necessarily mean that gross rates have increased, since the general BAF may have fallen because of the general drop in fuel prices.

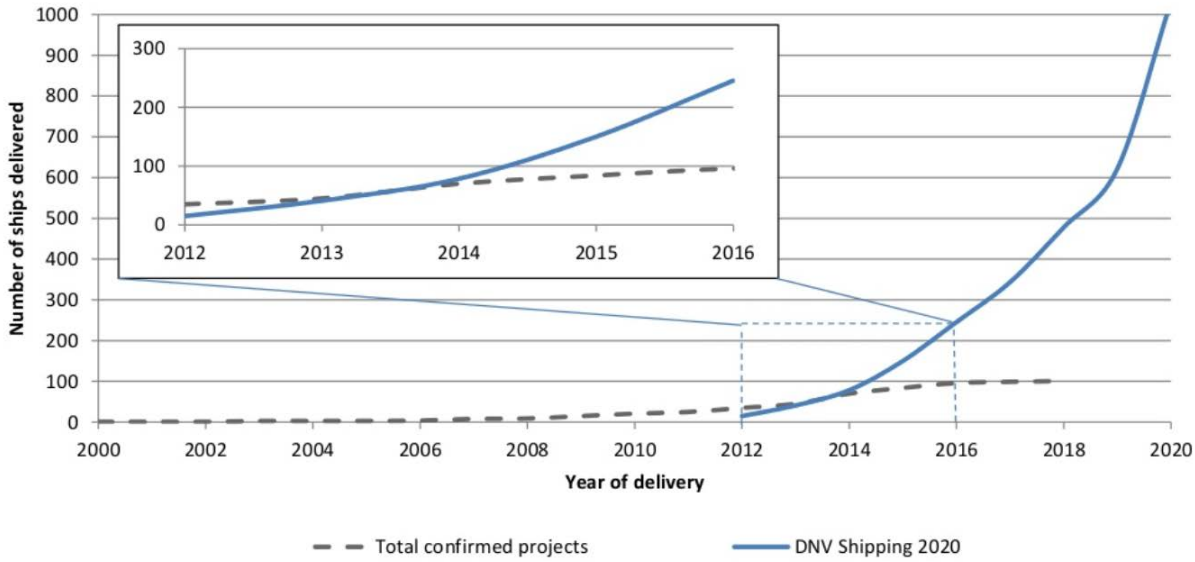

Figure 4.2 Development of LNG fuelled fleet (DNV-GL, 2015)

4.5. The ordering of LNG propelled vessels seems to be lower than expected

Probably due to the narrowing gap between LNG prices and the price of alternative fuels, the growth in the LNG propelled fleet seems to be lower than anticipated (Figure 4.2). Most actors seem to regard LNG as an option for the future, but maybe limited to coastal and inland shipping. Concerns about the availability of bunkering infrastructure and the global oil price drop, limits the interest in the technology at the moment. At least one order (Brittany Ferries; one new-building and three retrofits) has been cancelled (Pathak, 2015).

Currently (January 2015) the existing LNG-propelled fleet counts 57 vessels, and another 77 are on order, totalling 134 vessels. The prognosis made by DNV-GL in 2012 (Figure 4.2) anticipated a much higher growth rate, and an exponential growth when the next step in the global regulatory regime is closing in (in 2020). The current fleet is very much dominated by Norway (Figure 4.3), which has led the way in this market, first by introducing LNG propulsion on coastal ferries and then introducing this also for other vessels (offshore, RoPax and general cargo vessels). However, as the bunkering facilities have been gradually developed in ports around the world, the order book now has more balanced geographical distribution. In particular, the SECA regime along the east and west coast of North America has triggered a lot of orders for LNG-propelled newbuildings (Figure 4.3).

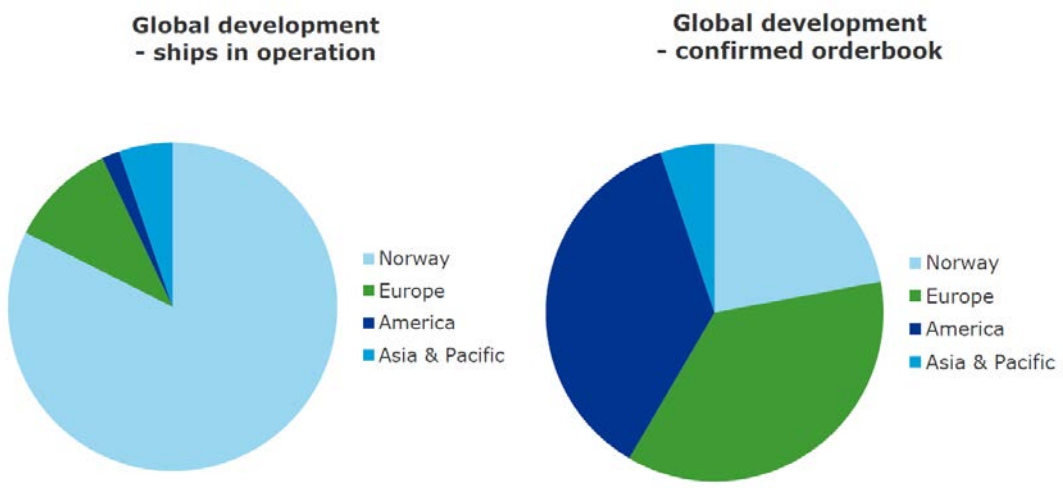

Figure 2.3 Regional development in world LNG propelled fleet (DNV-GL, 2015)

4.6. The growth in orders for scrubber systems seems to have slowed down

Although a complete overview over existing and ordered scrubber systems is lacking, there are probably around 200 vessels delivered or due with such systems installed (Eason, 2015a). 17 of 70 companies reviewed by MEC Intelligence (Pathak, 2015) report to have adopted scrubber technologies, mainly pertaining to passenger ferries, cruise vessels and RoRo vessels. A large cruise operator, active in both the North American and the North European SECA areas, is Carnival Cruises, which opts to retrofit 70 vessels with scrubber systems (Eason, 2015d). Most companies who install scrubber systems limit this to a part of their fleet, probably their newer vessels which have a significant remaining economic life. Examples are Transfennica which have ordered scrubbers for 6 out of 15 vessels in their fleet, and DFDS who is reported to install scrubbers on 20 out of 45 vessels. Orders for scrubbers doubled from April 2014 to September 2014, but grew only by 14% in the subsequent four months. This is probably due to the global oil price drop which has made the benefits from costly scrubber installations more limited at least in the short run.

Adding to the uncertainty around the payback-time for scrubber installations is the fact that some operators defer scrubber installations because of uncertainty about the future regulatory regime. This is partly regarding the planned tightening of global regulations in 2020 (which may be postponed), and partly about the potential conflict of open loop scrubber systems with EC regulations pertaining to emissions of seawater used by the scrubber system into the sea (Brett, 2014, Shettar, 2014, Eason, 2015d). Several manufacturers have developed scrubber solutions with different technologies, probably hoping that this market will take off when the new global limits of sulphur emissions come into force. Since the actual date for this to happen is somewhat unclear, and since technologies and fuel qualities are being developed to meet these new criteria, it seems that most operators are hesitant to install scrubber systems at this stage. The actual penetration of LNG propulsion in the years to come will also be an important factor regarding the interest for scrubber systems (Eason, 2015a).

4.7. There is a significant concern over lack of enforcement and non-compliance

There is a worry among actors that the enforcement of the new regime may not be good enough (Ljungberg et al., 2013, Eason, 2015e). This has triggered several initiatives both from the operator and regulator side. There has been a movement by the shipowner members

of the Trident Alliance, who have signed up to a charter of compliance to the sulphur emission rules, saying they want robust enforcement regimes to make sure that deliberate rule-breakers are caught and dealt with in a way that will be a strong deterrent to others (Eason, 2015e). The EU, through the European Maritime Safety Agency, has developed guidelines on how port state inspectors should go about checking for compliance: checking paperwork, log books and bunker delivery notes first, then turning to samples if needed. There is also a requirement in the making for all European countries to inspect at least 10% of vessels calling at European ports for sulphur compliance, and then to have fuel sampled on a certain percentage of those vessels (Eason, 2015e). Some countries (e.g. Finland) have moved to introduce a tougher penalty regime for non-compliance (Eason, 2014a), and port states inside SECAs have united to launch an information campaign to ensure shipowners are fully aware of the requirements of new environmental regulations (Eason, 2015b). Still, it seems that enforcement may have been given higher priority in the US case, where the Coast Guard is responsible for inspections.

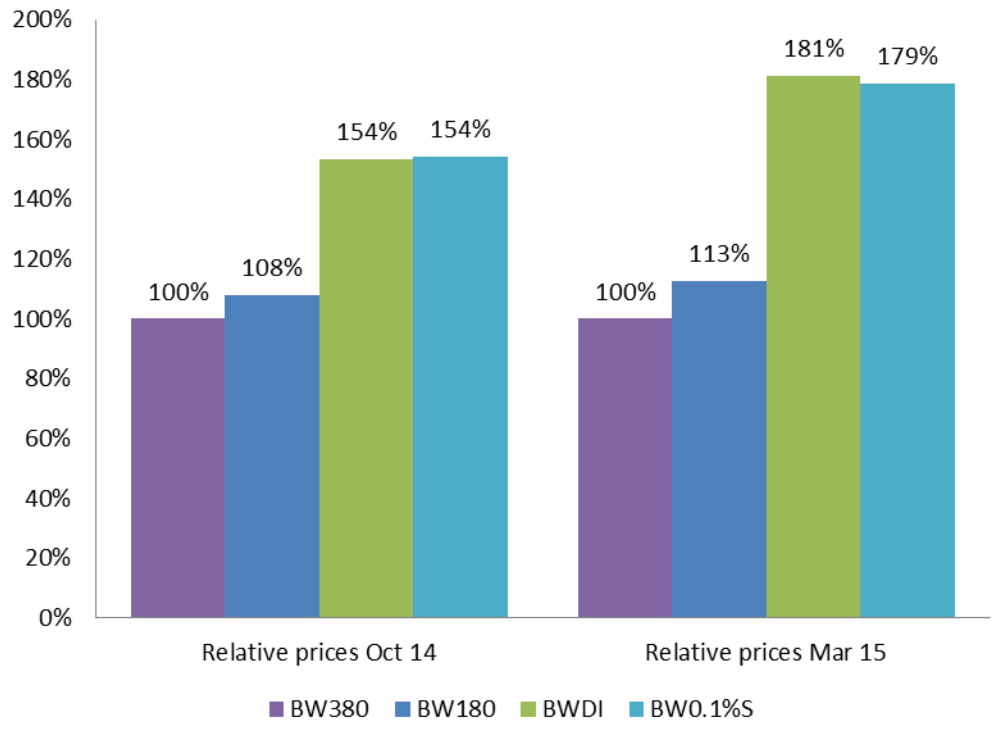

Figure 4.4 Relative prices of marine fuels October 2014 and March 2015 (own compilation based on data from Bunkerworld)

4.8. The relative price of diesel oils versus heavy oil products has increased

In Figure 4.4 we have compiled relative prices of fuel oils, based on prices from Bunkerworld in October 2014 (before the new regulations) and March 2015 (after the new regulations). Whereas there seems to be small price differences between the low sulphur diesel oils (BW0.1%) and regular diesel oils (BWDI), the relative difference between the heavy oil products (BW380 and BW180) and the diesel oils seems to have grown. For operators who previously operated on heavy oil, this means that relatively speaking, the new regime introduces a bigger difference regarding fuel costs outside and inside SECAs. However, the general drop in all fuel prices means that low sulphur diesel oil now costs about the same as heavier oils a few months ago (Figure 4.1).

5. DISCUSSION AND CONCLUDING REMARKS

Our review of expected impacts (Table 3.1), and early evidence about adaptations to the new regulatory regime, has shown that there is little evidence that suggests that the new regulations have had very dramatic impacts on the competitiveness of short sea shipping in and around the SECA area this far. However, this conclusion may to a large extent rely upon the concurrent drop in the price of crude oil and marine fuels. This drop has more or less compensated the increased costs of switching from IFO to low sulphur diesel. Since the evidence presented above indicates that this is the way the bulk of the fleet has adapted to the new regulations, the competitiveness of short sea operators may seem to be relatively unchanged after 1 January 2015. However, land based alternatives to short sea shipping are also, to a large extent, exposed to fuel prices. Diesel trucks and diesel trains have therefore also benefited from a drop in fuel prices. This means that the relative competitiveness of short sea shipping may still be somewhat weakened after all. Since truck transport, and possibly diesel trains, are usually regarded as more energy intensive, the benefit of falling fuel prices may be expected to be more significant for these modes more than for the shipping industry. However, there are still some factors that may moderate this picture. In Figure 5.1 and Figure 5.2 we have illustrated the late changes in the price of marine fuels compared to that of auto-diesel with and without taxes. All fuel prices have dropped between October 2014 and March 2015, but the marine fuels have dropped much more than auto-diesel, especially if we consider prices including taxes. Auto-diesel including taxes has only had a drop in prices by 8%, whereas the price of marine fuels (represented by the Bunkerworld Index – BWI) have on average dropped by 27%. This means that for ship operators who have switched from heavy fuel oils to low sulphur diesel probably still has lost some competitiveness versus land based modes, but that this impact seems to be quite small due to the more significant fall in the prices of marine fuels. Vessels who were already operating on diesel fuels have probably gained some competitiveness versus land based modes. It may in fact be that the "early movers" of the shipping industry, i.e. the ones that have taken heavy investments in new technology in the form of LNG-conversions / newbuildings or scrubber installations may have lost competitiveness in the short run, because the relatively heavy investments may have a longer payback-time under the current fuel prices.

The analysis of the early impacts does not indicate that the expected rise in operating costs and freight rates has not yet materialized, although many operators have announced a special element in the BAFs. These add-ons have probably been offset by a reduction in the regular BAFs this far. It is too early to assess any impacts on market shares, as freight statistics from 2015 are not available yet. The comparative picture of fuel costs could indicate that operating and/or capital costs may have increased somewhat for some actors, but that the impact is probably very small at the moment. However, if the prices of crude oil and oil products recover, this picture may change swiftly. Since the BAF sulphur add-ons have been implemented technically, a rise in fuel prices will rapidly be transferred to customers, possibly also affecting mode choice.

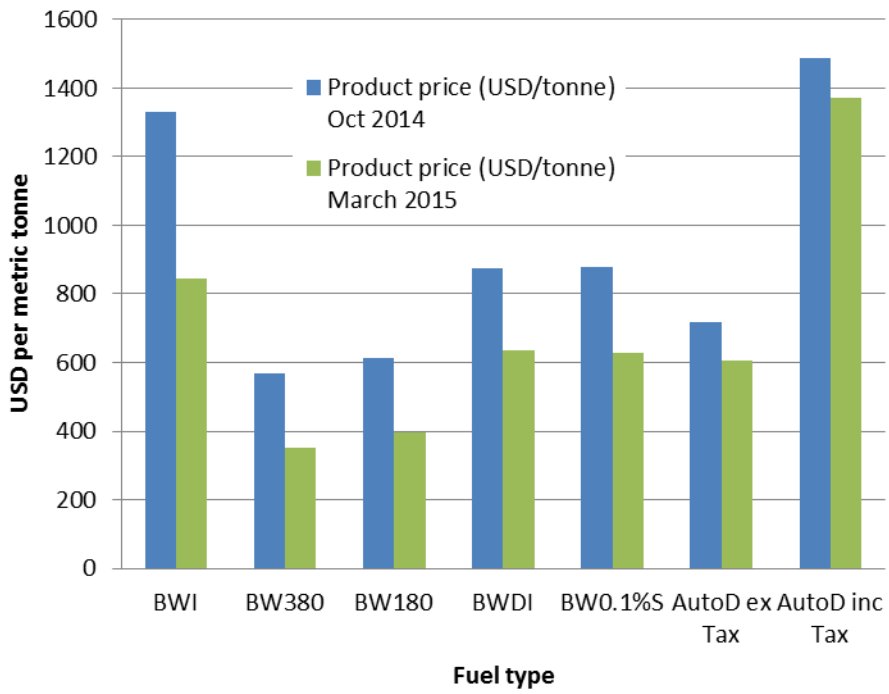

Figure 5.1 Average bunker and auto-diesel prices (own compilation based on data from Bunkerworld and Eurostat)

The expectations that in the short run most operators would switch to low sulphur diesel has been confirmed. However, the expected interest in LNG-propulsion and scrubber systems has been less prominent than anticipated. The number of LNG propelled vessels is still rising, but at a slower pace than the prognoses made by DNV-GL (Figure 3.2). This may be a temporary effect, stemming from the current fall in oil prices – and the smaller benefits in terms of lower fuel costs. If oil prices pick up again, this may speed up the ordering of LNG-propelled vessels. This still seems like an attractive option in the US market even at current prices. The same effects may also have affected the orders for scrubber systems, but in this case there are two other important factors limiting the attractiveness of such investments from a ship operator's point of view; the somewhat unclear EU regime with respect to a potential conflict with regulations of emissions to sea from open-loop scrubber systems, and the potential postponement of the next step in global sulphur regulations under the Marpol convention. Along with these factors that need to be addressed by the regulators, there is a technical development of scrubber systems and fuel qualities which make the option value of postponing investment decisions higher for the operators. These two technology options are of course not independent of each other as e.g. technology development with respect to scrubber systems may affect the comparative attractiveness of LNG propelled vessels and vice versa.

Ever since the Marpol Annex VI amendments were adopted, the industry has called for mitigating actions by governments, preventing the expected adverse effect on freight mode choice. This far national and regional governments have not introduced substantial instruments to compensate the shipping industry for increased costs, but there have been a few minor examples of national and regional instruments that may have sugared the pill for the shipping industry; Finland has supported investments in new technology (Ljungberg et al., 2013), and changed user fees or general taxation for short sea shipping (Ljungberg et al., 2013, Eason, 2014a). The Port of Gothenburg has launched 30% lower port dues in a four

year trial period for low sulphur vessels (Eason, 2014b). Denmark has supported infrastructure investments – either for e.g. LNG distribution, or to make SSS more competitive in general (Ljungberg et al., 2013). The Norwegian NOx-fund has contributed to the financing of LNG vessels and scrubber installations. The Motorways of the Seas programme under the EU has contributed to the Methanol-conversion of a Stena-ferry (Container Management, 2014), and the European Investment Bank finances two new LNG-propelled cruise ferries for Fjord Line (Becker, 2014).

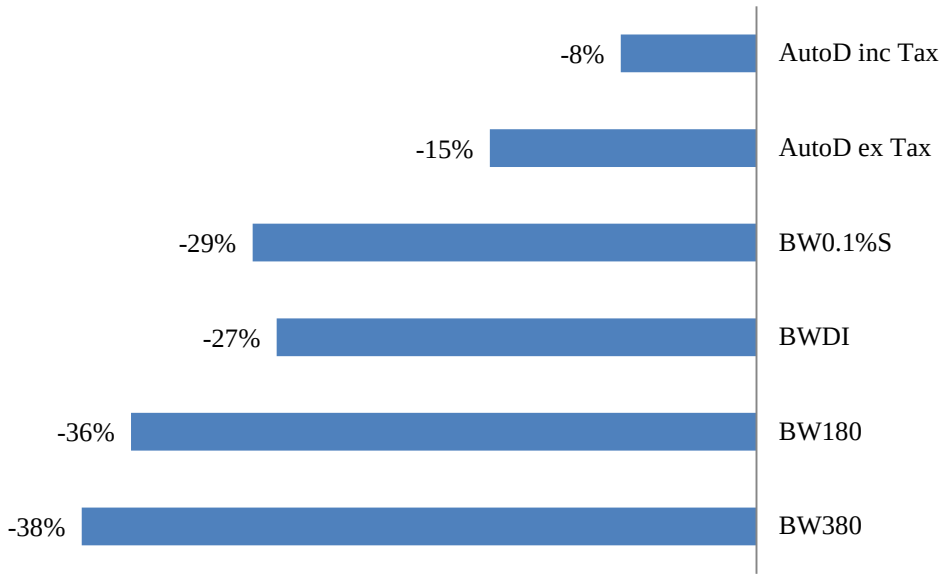

Figure 5.2 Relative price changes of fuels October 2014 to March 2015 (own compilation based on data from Bunkerworld and Eurostat)

This far, the expected adverse effects on freight mode choice do not seem to have materialized as expected. The few cases of closed down liner operations may have happened anyway even if operators to some extent blame the new regime. There are probably other challenges to the relative competitiveness of the short sea shipping industry that are more important than the increased fuels costs stemming from the SECA regulations. The case for short sea shipping as the green mode of freight transport could in most cases be made with respect to greenhouse gases, even before the recent regulations were adopted. However, the problem compared to the trucking industry has been large emissions of sulphur, nitrogen oxides and particles (Hjelle, 2014, Hjelle and Fridell, 2012). With the new Marpol regulations on sulphur and NOx, these reservations will be gone in a few years (when regulations are fully implemented) and the rationale behind the policy for moving cargo from land based modes to sea transport will be further strengthened.

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THE ADOPTION OF E-PROCUREMENT: LITERATURE REVIEW AND RESEARCH PROPOSITIONS

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ABSTRACT

Purpose
This research explores possible antecedents to the extent of e-procurement adoption in business firms.

Design/methodology/approach
The paper is based on a review of literature in purchasing management, electronic procurement and information technology adoptions to develop a conceptual model for e-procurement adoption.

Findings
The study has demonstrated how the perceived role of the procurement function, the perceived costs of e-procurement, the size of the supply base, technology literacy, the size of the purchasing firm and the perceived usefulness of e-procurement affect the extent of e-procurement adoption. The study also presents a set of propositions that can be tested empirically in future research.

Research limitations/implications
The suggested propositions in this study need to be explored and tested further based on empirical data in order to provide more validity to the main conclusions of this research.

Practical implications
This research provides some valuable insight into significant antecedents to the extent of e-procurement adoption.

Original/value
This study focuses on the antecedents to e-procurement adoption, and has in particular, explored possible contingent effects of these factors on e-procurement adoption.

Keywords: E-procurement, technology adoption, technology literacy, procurement function role, supply base size, size of the firm, perceived usefulness, and the perceived costs of e-procurement technologies.

1. INTRODUCTION

The adoption of information technology in procurement management has the potential for creating competitive advantages for business firms. Traditionally, most of the activities associated to the procurement function are rather routinized, and involve a large amount of information processing and communication factors that can be handled efficiently by proper information technologies (Teo et al., 2009). In spite of hosting enormous potentials for performance improvement, the adoption of information technology in the procurement function has received limited attention, and proper information technologies are not used fully to support procurement activities even though information technology made its way to procurement function before the 1970s.

The adoption of information technology in order to support the procurement function is termed as e-procurement. It ranges from the very basic applications of technology such as the use of e-mails for procurement correspondence purposes to the full automation of the procurement process. The existing literature has pointed out several operational and strategic benefits for e-procurement adoption in business-to-business relationships, including costs reductions obtained by operational and process efficiency (Croom and Brandon-Jones, 2005; Teo et al., 2009; Smart, 2010), high supply chain transparency (Hawking and Stein, 2004; Puschmann and Alt, 2005), and improved market intelligence (Hawking and Stein, 2004). Other benefits are improved purchasing leverage (Hawking and Stein, 2004; Puschmann and Alt, 2005), better supplier management (Puschmann and Alt, 2005), and time saving in the routine purchasing activities (Hawking and Stein, 2004; Teo et al., 2009).

Following its great potential, e-procurement was projected to become an important element in the management of supply chains in both the private and public sector, and its rate of adoption was expected to increase as the early adopters shared their experiences with potential later adopters (Davila, Gupta and Palmer, 2003). However, the adoption of e-procurement technologies has been slower than expected with most companies making limited use of these technologies by applying only a few selected e-procurement technologies to facilitate procurement activities (Puschmann and Alt, 2005).

For instance, the findings of Wyld (2004) indicated that only 30 percent of the surveyed companies used e-procurement in their requests for quotations, some 25 percent used only online auctions, and 33 percent used it only to access e-marketplaces. Furthermore, several evidences from the literature show that most of the organisations that adopted e-procurement failed to realise the claimed benefits (Smart, 2010). It is therefore worthwhile to examine the causes of this rather slow and limited adoption of e-procurement, and this study is guided by the following research question: *What factors influence the extent of e-procurement adoption by purchasing organisations?*

Several studies (e.g. Hawking and Stein, 2004; Vaidya et al., 2006; Davila et al., 2003) have discussed the barriers to e-procurement adoption. One striking observation is that most of the existing studies do not discuss the e-procurement adoption barriers in the context of the existing technology adoption theories. As a point of departure, this study reviewed the evolution of the role of the procurement function, the history of information technology application in procurement, and use relevant technological adoption theories to explain the reasons for that rather modest adoption of e-procurement technologies.

This article is organised in the following way: In the second section, we present the methodology used, and the third section focus on the literature review. In the fourth section, we propose the conceptual model and research propositions that show how relevant variables included in this research affect the extent of e-procurement, and the last section presents the discussion and conclusion.

2. METHODOLOGY

This paper uses a literature survey methodology, which is defined as the documentation of the comprehensive review of the published and unpublished works from secondary sources of data in the area of specific interest (Vaidya, Sajeev and Callender, 2006). Thus, we reviewed published papers on e-procurement to enrich our knowledge on the adoption of technology in the procurement function. We further review literature on the evolution of the procurement function and the history of technology application in the procurement function. The latter review informed us on the causes of failures for the technologies that preceded e-procurement, and the theories of technology adoption were reviewed to enhance our understanding of theories that may explain e-procurement adoption.

3. LITERATURE REVIEW

3.1 The Evolution of the Procurement Function

For a long time procurement has been considered a clerical function. In the 1970s, it began to receive more attention from academicians, and its importance as a significant administrative function was recognized. Michael Porter included supplier power and buyer power as significant forces that shaped competitive strategies in his seminal paper in 1980. Porter prompted organizations to start thinking of procurement management as a strategic function rather than simply administrative operations (Quesada, Gonzalez, Mueller and Mueller, 2010). Since then, procurement management has become more important and evolved from being viewed as an administrative activity to be considered a strategic function in the value chain (Hawking and Stein, 2004; Aboelmaged, 2010)

The increased importance and strategic view of the procurement function can be traced to new trends in global sourcing, and the emphasis on time to market. Other factors include quality based competition, customer uncertainty, and the need to reduce bottom-line costs. Procurement has been a costly activity for businesses over the years with slow and manual business procedures and processes for handling purchasing transactions, and firms spend more money on the procurement of materials and services to support business operations than the total expenses for all other functions (Kalakota and Robinson, 2001).

For each dollar of sales, some 0.5 to 0.6 is spent in the procurement of goods and services (Hawking and Stein, 2004), and this consideration of procurement costs is emphasised by Van Weele (2005) stating that procurement expenditures account about 50 to 80 percent of the sales figures, and reach up to 90 percent in industries like petroleum. Even in the service industry, the procurement costs figure is around 35% (Kothari, Hu and Roehl, 2005). Accordingly, there is now a stronger focus on reducing procurement costs and how to increase the contribution of the procurement function in value creation, and in particular on how information technology can support the procurement function for these purposes (Teo et al., 2009; Smart, 2010).

3.2 The Development and Adoption of Technology in the Procurement Function

The e-business phenomenon emerged in the late 1990s and arose through the proliferation of internet as a platform for inter-organisational systems, and e-procurement is the most significant and important factor in the development of e-business in supply chain management (Croom and Brandon-Jones, 2005). Even though some literature contributions (e.g. Neef, 2001; Puschmann and Alt, 2005; Vaidya et al., 2006) clearly suggest that e-procurement

emerged in the late 1990s, the origin of e-procurement is still uncertain and debated among academics (Vaidya et al., 2006). One reason for the existing debate is that some researchers and practitioners do not differentiate e-procurement technologies from the preceding technology solutions in procurement (Kalakota and Robinson, 2001; Hawking and Stein, 2004), and perceive e-procurement to be synonymous with other technological solutions used in procurement management such as electronic data interchange (EDI) (cf. Neef, 2001).
E-procurement systems are different from inter-organizational information systems (IOISs) that involve EDI. They are open systems that enable firms to reach and transact with suppliers and customers in virtual markets without investing in dedicated systems (Dai and Kauffman, 2001).
Prior to the e-procurement systems in the 1960s, a significant part of the supply chains and B2B purchasing arrangements were conducted via EDI (Vaidya et al., 2006), and the discussions in the procurement and supply chain literature focused on EDI (Smart, 2010). Moreover, EDI was repeatedly promoted as a business model of the future, but suffered from slow adoption and stunted growth. For instance, In North America and Europe, EDI had a low take-up rate of some 2 percent (Reason and Evans, 2000).
The take-up rate of EDI was hindered by its proprietary nature, expensive implementation, lack of agreed standards (Neef, 2001), and the stringent syntax requirements which necessitated a strong technological integration between the trading partners (Teo et al, 2009). Moreover, it was too complicated and expensive for small enterprises to set up a dedicated EDI connection (Neef, 2001). Notwithstanding its weaknesses, EDI systems continued to enable organisations to improve supply chains management, and to achieve efficient data and information processing abilities, but still very few organizations used it due to the substantial costs involved in implementing and running such systems (Dai and Kauffman, 2001). For instance, in the beginning of the 2000s, the connection to EDI implied investments costs of some 25.000 – 40.000 USD on average (Neef, 2001).
Because of the commercialization of internet and World Wide Web in the 1980s and its proliferation in the 1990s, it became evident that EDI was a too complex, cumbersome and expensive technology for procurement purposes.
As an alternative, the internet systems provided a relatively simple and cheap technological solution in business-to-business procurement. However, it was not until the late 1990s that the concept of internet based procurement or electronic procurement emerged (Teo et al., 2009). The diffusion of internet usage in procurement created a potential for reorganizing the purchasing of maintenance, repair and operational products, which consumed a very large portion of the procurement department time, and accounted for about 80 percent of all purchasing transactions pertained to indirect goods and services (Wyld, 2004; Puschmann and Alt, 2005).

3.3 Technology Adoption Theories

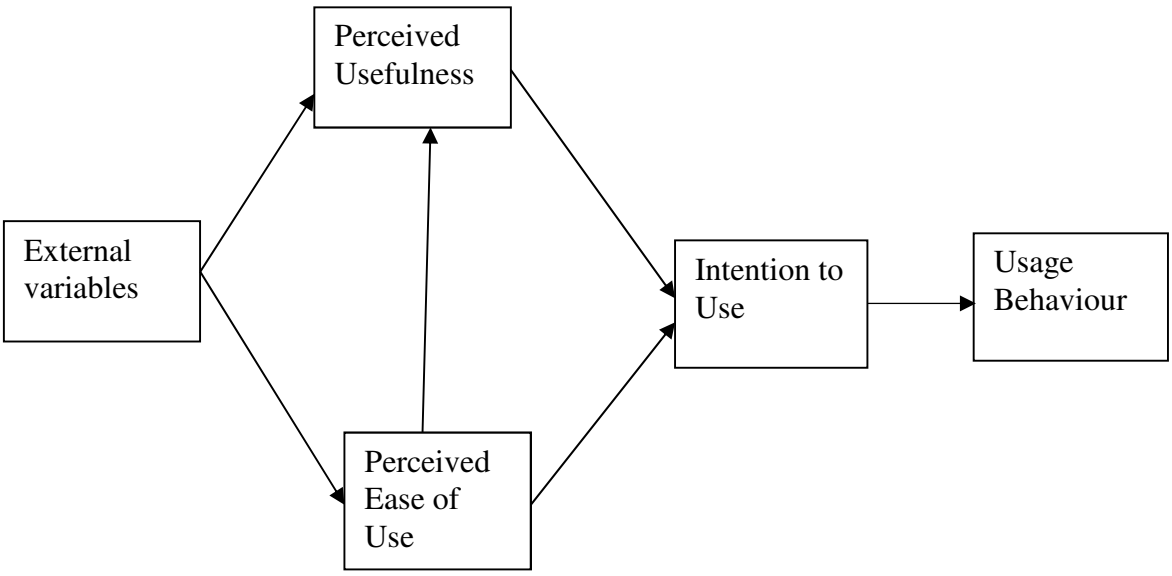
E-procurement is a multifaceted phenomenon that cannot be easily explained by one single theoretical framework (Azadegan and Teich, 2010). In order to better comprehend possible causes of slow adoption of the e-procurement technology, we will conduct a literature review of technology adoption theories.
Theoretical models explaining the determinants of the adoption and subsequent use of new technologies started to emerge in the early 1960s with the classical contribution of Rogers (1962), and developed further in the middle of the 1970s with the introduction of the theory of reasoned actions by Fishbein and Ajzen in (1975).
Since then, researchers have developed several theories to study technology adoption. Some basic contributions include the theory of planned behaviour (TPB), and the technology

acceptance model (TAM) which developed as an extension of Ajzen and Fishbein's (1980) theory of reasoned action. Other technology adoption theories are (1) the unified theory of acceptance and use of technology (UTAUT) by Venkatesh et al., (2003), (2) the technology-organisation-environment model (TOE) by Tornatzky and Fleischer (1990), and (3) the motivation-opportunity-ability model (MOA).
The technology acceptance model (TAM) and the technology-organization- environment model (TOE) are identified as the most relevant theories that provide relevant knowledge on the objective of this study, and will be reviewed in detail in the subsequent sections.

3.3.1 The relevance and Importance of the Technology Acceptance Model (TAM)

Davis et al. (1989) introduced the technology acceptance model (TAM) as a framework to explain computer usage behaviour. Since its introduction, this model has been successfully applied to study the application of information technology solutions in several industry settings (Adamson and Shine, 2003; Bruner and Kumar, 2005; Chau and Hu, 2001; Hu et al., 1999). Most of the earlier studies used TAM to study the adoption of information technology at the individual level. However, there is evidence that some scholars have successfully used this model to study the information technology adoption at the organisation level (Lee and Park, 2008; Obal, 2013).
Several empirical studies have demonstrated that the basic factors in the TAM-model enable to explain a substantial proportion of the variance of technological usage intentions and behaviour. Moreover, TAM has a strong link with other technology adoption theories including the theory of reasoned action (TRA) and the theory of planned behaviour (TPB) as advocated by Venkatesh and Davis (2000).

Figure 1: The TAM-Model (Technology Acceptance Model, Venkatesh and Davis, 2000)



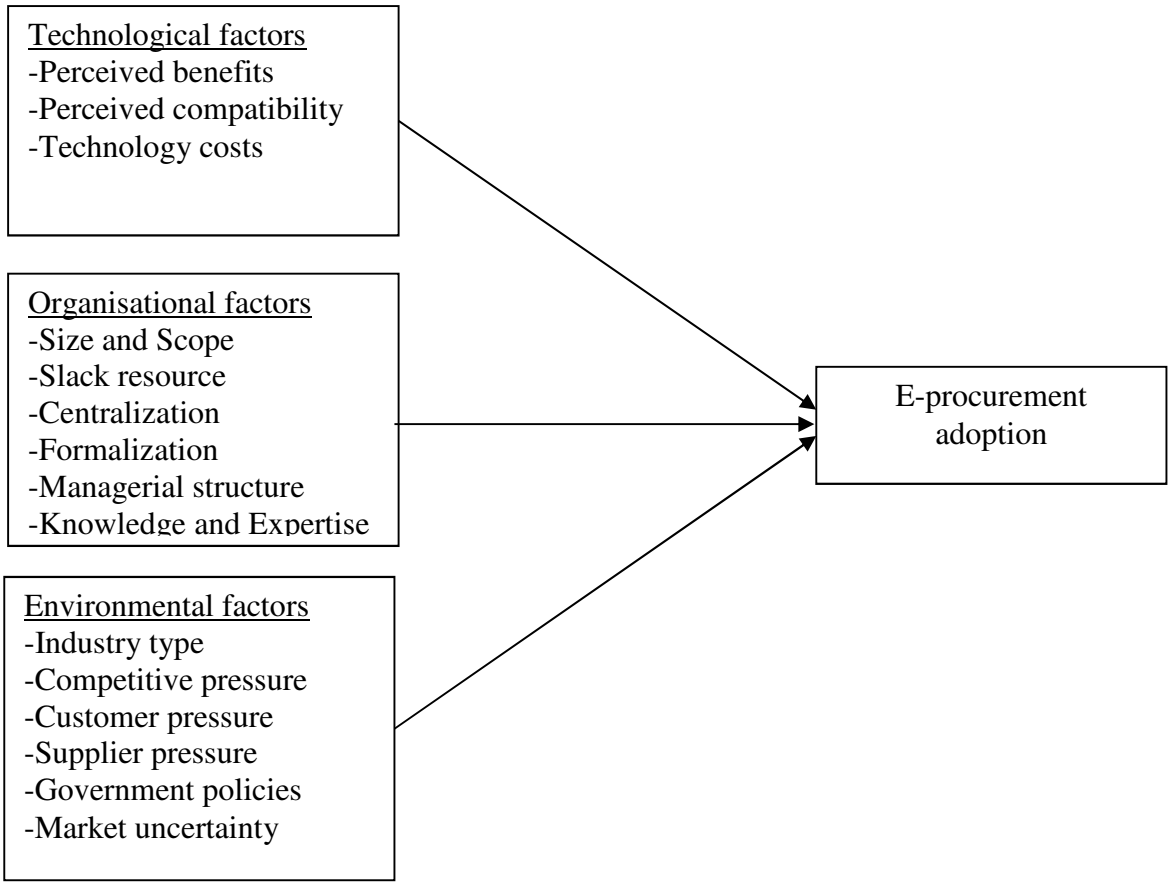
The intention of the TAM-model is to provide reliable determinants of general technology acceptance (Chau, 1996), and this model has been able to explain user behaviour for a broad set of computing technologies and across several user populations (Davis et al., 1989; Chau,

1996). Davis (1986) asserts that the behavioural intention to use technology is determined by two beliefs: (1) perceived usefulness and (2) the ease of using the system (confer Figure 1.).
The TAM-model predicts that the effects of external variables (e.g. technology characteristics, development processes and training) on the intentions to use a new technology are mediated by the perceived usefulness and perceived ease of use associated to new technologies. The perceived usefulness in turn is influenced by the perceived ease of use; that is, the easier the technology is to use, the more useful it will be perceived by business actors (Venkatesh and Davis, 2000).
After years of validation efforts, TAM is now well established as a powerful and robust model for predicting user acceptance of new technologies. Based on several empirical tests of the model (e.g. Aboelmaged, 2010), the perceived usefulness has been consistently shown to be the basic determinant of usage intentions, and verified by a regression analysis with a standardized regression coefficient of 0.6 in the study by Venkatesh and Davis (2000). The perceived ease of use has also been shown to influence the user intentions significantly.

3.3.2 The Technology – Organization – Environmental Framework (TOE)

A theoretical model that seeks to explore factors influencing the adoption of information technology needs to consider factors that influence the propensity to adopt, implement and diffuse technology innovations, and some of these factors are rooted in the specific organisational and environmental context of business firms (Lin and Lin, 2008). The TOE-framework captures these aspects of the organization and makes a comprehensive framework for studying the adoption of new technologies (Tornatzky and Fleischer, 1990).
The technology aspect of the TOE framework depicts technological factors that are relevant to the organisation in its pursuit of business objectives (Duan et al., 2012), which includes the perceived benefits of adopting new technologies, compatibility problems and the costs of adopting a new technology (Ghobakholoo et al., 2011).
The organization aspect is captured by several descriptive measures, including firm size and economics of scope. Furthermore, much emphasis is put on informal electronic linkages and communication issues, amount of organizational slack resources, as well as centralisation, formalisation, and the complexity of the firms managerial structure (Teo et al., 2009; Walker and Harland, 2008).
Finally, the environmental aspect describes the industry settings in which business firms conduct their business (Lin and Lin, 2008; Teo et al., 2009; Duan et al., 2012), and this aspect includes industry type, competitive pressure, customer pressure, supplier pressure (Bordonaba-Juste et al., 2012), government policies, and market uncertainty (Li and Xie, 2012). The technological, organisational and environmental factors are summarised in figure 2 below.
The TOE framework is seen a valuable tool to study the adoption and diffusion of new technologies (Bordonaba-Juste et al., 2012), and several researchers in various information system domains have taken advantage of this framework to study the adoption and diffusion of information systems. This concerns Kuan and Chau (2001) who used the TOE framework to study electronic data interchange adoption (EDI), Pan and Jang (2008) who applied this framework to explain the adoption of enterprise resource planning. Ramdani et al. (2009) applied the TOE framework to predict the adoption of enterprise systems in small and medium enterprises, Lin and Lin (2008) followed this framework to study the determinants of e-business diffusion, and Mishra et al. (2007) applied the TOE framework to study the antecedents and the consequences of internet use in procurement management.

Figure 2: Technology-Organisation-Environment Model (TOE-model)



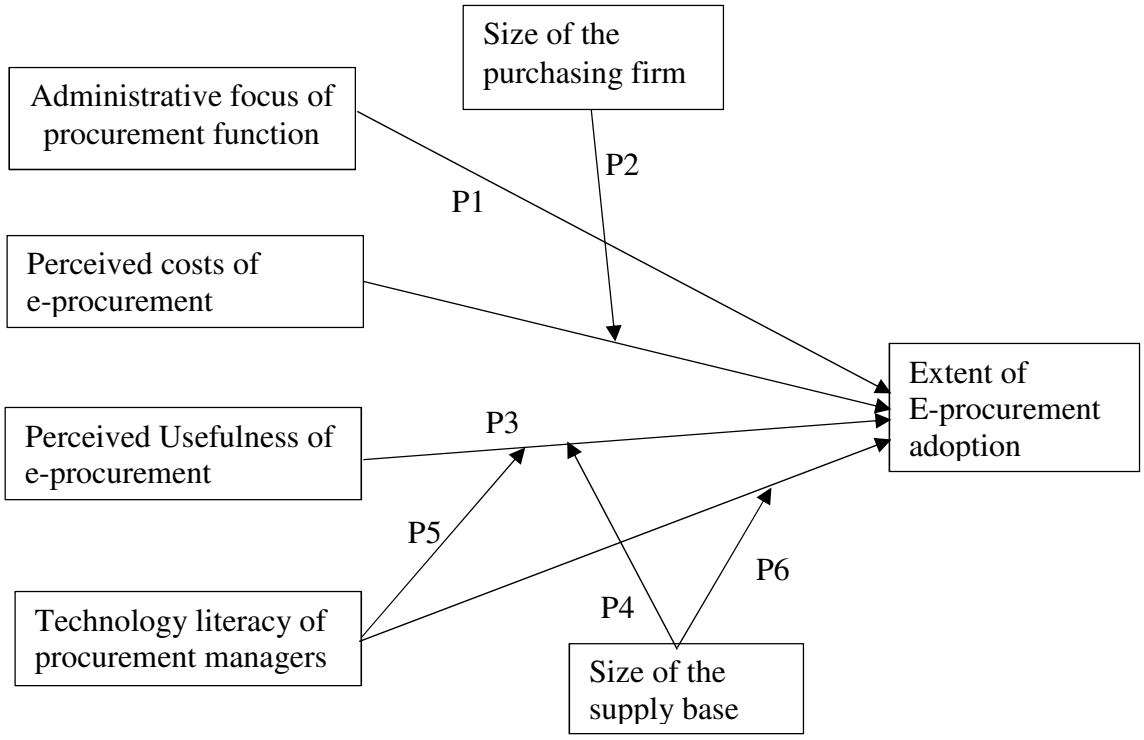
Source: Constructed from literature review, mainly Toe et al. (2009), Li and Xie, 2012, and Bordonaba-Juste et al., 2012

Furthermore, Literature (e.g. Mishra et al., 2007; Huntgeburth et al., 2012) suggests that the TOE framework provides useful guidelines for exploring e-procurement adoption, and this study will apply some of the variables from this theoretical framework to explore some factors that influence the extent of e-procurement adoption in business firms.

4. CONCEPTUAL MODEL AND RESEARCH PROPOSITIONS

Our conceptual model is constructed by combining some organizational and technological factors from the TOE framework and some elements from the technology acceptance model (TAM). The conceptual model is also supplemented by the literature on the evolution of the role of the procurement function in business firms, the history of information technology application in buyer–supplier relationships. Our arguments concerns the way the following factors affect the extent of e-procurement adoption:(1) administrative perception of procurement function, (2) perceived costs of e-procurement, (3) the size of the supply base, (4) the technology literacy of the managers in the purchasing organisation, (5) size of the purchasing firm, and (6) perceived usefulness.

Figure 3: Conceptual Model



4.1 The Administrative Focus of the procurement function

Based on our literature review, it is noted that for over half a century there has been a shift in perception of the procurement function from clerical to a strategic function, and information technology is seen as a key catalyst to this regard. The introduction of e-commerce via internet made companies to notice the strategic potentials of the procurement function (Teo, Lin and Lai, 2009). Thus, companies started to take advantage of the emergence of internet in the late 1990s, and used various internet technologies to facilitate procurement activities (Marston and Baisch, 2001).

Nevertheless, the strategic role of the procurement function is not universally recognized. Significant number of firms have continued to treat it as an administrative function, and some scholars (e.g. Kaufman and Carter, 2004) regard procurement as supporting function with a tactical role in business firms. Tassabehji and Moorehouse (2008) found that business firms consider the strategic importance of the procurement function to be rather modest. This administrative orientation has some consequences on e-procurement adoption. The extent of adoption of e-procurement is likely to be lower for firms with an administrative focus of procurement function than for firms with more strategic orientation. Accordingly, we pose the following research proposition:

Proposition 1: Stronger administrative focus on the procurement function is negatively related to the extent of e-procurement adoption

4.2 The Perceived Costs of e-procurement and Firm Size

E-procurement technologies involve the use of internet and related technologies to enhance the efficiency of procurement activities (Teo et al., 2009). The unique features of internet and related web based technologies have the potential to support procurement activities and improve the procurement process. Some of these technologies include e-mails, discussion forums, video conferencing, extranet (Garrido-Samaniego et al., 2010), internet search engines, electronic-catalogues, customized e-procurement software, electronic auctions, and electronic market places (Teo et al., 2009)

Accordingly, some scholars (e.g. Marston and Baisch, 2001) noted that the use of e-procurement to perform basic activities such as purchase orders and invoicing, as well as payments processing could reduce transactional costs from around 1 dollar to 10 cents. Nonetheless, setting up e-procurement systems would require substantial capital expenditures (Gunasekaran et al., 2009) in addition to operating and training costs (Teo et al., 2009). These costs may affect the extent of e-procurement adoption, and this effect is likely to be contingent on the size of the purchasing firm.

Small firms are characterised by the condition that Welsh and White (1981) termed as a *resource poverty,* which spans from financial to human resources, and the majority of small firms have limited budgets and shortage of skilled labours (Deros et al., 2006). Due to such resource poverty, small firms are more likely to consider the consequences of the costs of implementing e-procurement to attenuate their adoption of e-procurement more than what is the case for large firms. We therefore propose the following proposition:

Proposition 2: The effect of the perceived costs of e-procurement technology on the extent e-procurement adoption is more negatively shaped for small firms than for large firms.

4.3 The Size of the supply base

The size of the supply base refers to the number of suppliers serving the purchasing firm. We will argue that firms with a large supply base are more motivated to adopt e-procurement technologies than firms with a rather small supply base, and transaction cost theory provide a strong theoretical foundation for this reasoning. The unit of analysis in transaction costs analysis is the interface between the purchasing firm and its suppliers (Choi and Krause, 2006). As the number of supplier increases, the frequency of exchange will also increase and hence the administrative unit costs associated to specific governance structures (Williamson, 1985; Cai, Yang and Hu, 2010). Examples of such administrative costs include data entry, invoice processing, correcting of errors in paperwork, order expediting and the handling of quality problems (Kothari, Hu and Roehl, 2005).

Accordingly, e-procurement provides an opportunity to reduce administrative costs and time spent in the management of the supply base. By automating laborious routines of the purchasing function, more time is released to strategic purchasing activities (Kothari, Hu and Roehl, 2005). Hence, firms with a large supply base are expected to be highly motivated to use e-procurement solutions than the firms with a small supply base. Accordingly, we suggest the following proposition.

Proposition 3: The size of the supply base is positively associated to the extent of e-procurement adoption

4.4 The Size of the Supply Base and Perceived Usefulness

The attraction of business firms to e-procurement adoption is shaped by the perceived usefulness of this technology, and it is well documented that the perceived usefulness enforces new technology adoption (Aboelmaged, 2010; Duan et al., 2012; Huntgeburth et al., 2012).

At an individual level, perceived usefulness is seen as the extent to which a person believe that using a particular system will enhance his or her job performance (Lee and Park, 2008). At the organisation level and in business-to-business relationships, the perceived usefulness depends on both costs and the benefits of adopting new technology. Thus, the technology is perceived to be useful if its benefits outweigh the sacrificed costs (Obal, 2013). This trade-off between the benefits and costs is reflected in a perceived value, and can directly influences the adoption rate of e-procurement (Kim, Chan and Gupta, 2007).

Hence, a firm with a large supply base should perceive e-procurement technologies as more beneficial due to the prospect of reduced administrative costs and reduced time associated to a broad set of purchasing administration activities as the supply base increases. Accordingly, the perceived effect of the usefulness of e-procurement on the extent of e-procurement adoption is expected to increase as the size of the supply base increases, and we propose:

Proposition 4: The effect of the perceived usefulness of e-procurement on the extent of e-procurement adoption is significantly enforced by the size of the supply base.

4.5 Technology Literacy and Perceived Usefulness

Technology literacy concerns the ability of users to understand and use technologies (Bertot, Jaeger and Grimes, 2010). The degree of technology literacy and the previous experience in using technologies constitute important variables in explaining technology adoption (Corrocher, 2006). The most recent research have called for greater attention to this variable, and in particular for studies geared on understanding technology adoption (Magsamen-Conrad et al., 2015).

The perceived benefits of e-procurement depend strongly on the users' level of technology literacy, and this study focuses on the technology literacy of procurement managers. Some research contributions have shown that technological literacy on the management side is very critical in increasing operational efficiency of business firms (Wilbon, 2002). It is worth noting that the adoption of e-procurement or any other kind of information technology has to be done through a top down approach (Teo et al., 2009), and the managers with high technological literacy can easily realise the effect of e-procurement adoption on organisational performance, and provide necessary support needed for e-procurement implementation. Thus, technology literacy might interact with perceived usefulness to increase the extent of e-procurement. Therefore, we suggest the following proposition.

Proposition 5: The effect of the perceived usefulness of e-procurement on the extent of e-procurement adoption is significantly enforced by the level of procurement manager's technology literacy.

4.6 Technology Literacy and the Size of the Supply Base

We expect the technology literacy of procurement managers and the size of the supply base to have an interaction effect on the extent of e-procurement adoption. Based on knowledge from organization behaviour literature, top manager make most of the strategic decisions in the organisations and they rarely make decisions in isolation. Instead, decision makers more often receive inputs from advisors, and the characteristics of the advisor provide important influence on the extent of advising activities (Tost, Gino and Larrik), and decision makers will assign more weight on the advices when the advisors possess solid experiences and knowledge (Feng and MacGeorge, 2006).

Solid technological knowledge among procurement managers should enforce the importance of their advices to the top management regarding e-procurement adoption. Thus, better technology literacy should enforce the ability of procurement managers to influence the adoption of e-procurement. The size of the supply base concerns the motivation for adopting e-procurement technologies in order to reduce administrative transaction costs. Accordingly, the effect of technology literacy on the extent of e-procurement adoption should be enforced as the size of the supply bases increases, and we propose:

Proposition 6: The effect of the procurement manager's technology literacy on the extent of e-procurement adoption is significantly enforced by the size of the supply base.

5. DISCUSSION AND CONCLUSION

5.1 Theoretical Considerations, Limitations and Further Research

The technology acceptance model (TAM), the technology–organization–environment framework (TOE) and contributions from the purchasing management literature informed the conceptual model for this study. Based on the TOE-framework, the perceived cost of e-procurement technologies, the technology literacy of the procurement managers and the size of the firm were identified as important variables in understanding the extent of e-procurement adoption. The current study has also used the technology acceptance model (TAM) to demonstrate how the perceived usefulness of e-procurement technologies among managers influence the extent of e-procurement adoption. Moreover, the purchasing management literature were reviewed and two variables including the administrative focus of the procurement function and the size of the supply base were identified as relevant variables in explaining the extent of e-procurement adoption, and included in the conceptual model.

Most of the earlier studies on e-procurement technologies have focused on factors affecting the adoption of e-procurement and paid limited attention to the variations of the extent of e-procurement adoption across purchasing firms. Nonetheless, the studies that focus on the extent of e-procurement adoption have started to emerge and demonstrated that the perceived costs of implementing new technology and the size of the firm are significantly associated to the extent of adoption of e-procurement (Teo et al., 2009). This study contributes to this research stream by arguing that the perceived costs of technology may vary across firms depending on their size. Hence, a consideration of the size of the firm as a contingent variable might enlighten our understanding on how the perceived costs of technology affect the extent of e-procurement adoption.

The reviewed literature has shown that the procurement function is not fully recognized to play a strategic role in the organization, and some managers still do not appreciate the strategic importance of the procurement function, and thus let the clerical staff take the

main responsibility for this function as part of their administrative duties (Yusuf, 2004). In this study, we view the administrative perception of the procurement function as a factor that stymie the scale of e-procurement adoption, and therefore explains the variation in the extent of e-procurement across organisations.

Technology literacy has been demonstrated as having a positive effect on the adoption of new technology (Ferro, Helbig and Gil-Garcia, 2011; Mac Cullum, Jeffrey and Kinshuk, 2014). However, most of the earlier studies on technology literacy have focus on the adoption of technology at an individual level (Ferro et al., 2011; Mac Cullum et al., 2014). Our study contribute to the existing literature by arguing that the technology literacy plays an important role in technology adoption also at the organisation level. Since the technology adoption is a top down decision, the procurement managers' level of technology literacy will affect the extent of e-procurement adoption in the organisation.

The technology literacy may also act as a contingent factor when we consider the effect of perceived usefulness on the extent of e-procurement adoption. Procurement managers who possess a high level of technology literacy tend to perceive e-procurement technologies as more useful than low skilled managers who are unable to see the potential advantages of e-procurement. Thus, high technology literacy among procurement managers should enforce their ability to convince the management about the strong advantages of e-procurement.

The purchase and supply management literature have associated the size of the supply base with transaction costs (Choi and Krause, 2006; Cai, Yang and Hu, 2010), and as the supply base increases, the administration and coordination costs incurred by the purchasing firm increases. Our study introduced the size of the supply base as a variable that may motivate the adoption of e-procurement technologies, and hence enforce the extent of e-procurement adoption. As the size of the supply base increases, purchasing firms may be more motivated to increase the extent of e-procurement use in order to reduce transaction costs. However, the effect of the supply base size may also coincide with a usefulness dimension and technology literacy of procurement managers, and hence enforce the effect of the perceived usefulness on e-procurement adoption.

5.2 Limitations and Further Research

The main limitation of this study is that the suggested propositions are restricted to a literature survey. Thus, the empirical testing of the hypotheses related to the propositions put forth by this study will provide more information on the proposed reasoning and conclusions of this study.

Moreover, the factors that affect the extent of e-procurement adoption are not limited to the factors incorporated in the conceptual model in this study. The technology literacy of the top management, the state of the development of supporting software industries, internet service providers, and the financial institutions' facilitation of electronic transactions are all examples of factors affecting the speed and success of e-procurement adoption and call further research.

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Gaining Flexibility and Responsiveness via Control and Integration of Logistics Information in Upstream Oil and Gas Logistics: Petrobras Case Study

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ABSTRACT

Purpose

The purpose of this paper is to advance research related to understanding of how flexibility and responsiveness is achieved in highly complex logistics environments during day-to-day operations.

Design/methodology/approach

In our study, we applied the constructs from information processing theory and coordination theory to investigate the ways, in which operational flexibility and responsiveness of the system are accomplished. An explorative case study of coordination practice from oil and gas upstream logistics provides practical evidence and additional insights about the key elements of coordination for operational flexibility and responsiveness.

Findings

The main findings of the study reveal the importance of collaborative environment and integrated information, communication and decision-making structures in achievement of operational flexibility and responsiveness.

Research limitations/implications
This paper contributes to logistics flexibility literature, with the findings from single case study. This approach helped to get in-depth understanding of the phenomena but at the same time limited generalization of the results. Further research should investigate the relevance of the findings to inter-organizational contexts and other industrial settings.

Practical implications
This research highlights the importance of collaborative environment, control and integration of logistics information, which managers need to consider during design of logistics organization.

Original/value
Defining information and decision structure requirements of the flexible organization has made an empirical and theoretical contribution to the flexibility and responsiveness achievement literature. The application of an information processing perspective to the study of flexibility represents a novel approach to the study of the phenomena.

Keywords: Flexibility, Responsiveness, Coordination, Oil and gas, Logistics, Offshore.

1. INTRODUCTION

In the light of today's complex and rapidly changing business environments, companies are continuously looking for the ways to respond to these changes and dynamics. The businesses face high level of uncertainty arising from globalization and outsourcing, rapid technology changes and shortened product lifecycles, as well as high level of service and responsiveness requested by customer (Handfield and Nichols, 2002; Bernardes and Hanna, 2009; Williams et al., 2013). Under such conditions, the ability to respond timely to changes in the environment and market needs becomes crucial. To some extent, the environments in which some businesses operate are comparable to environments of fast response organizations. According to Faraj and Xiao (2006), fast response organizations are operating under a high level of uncertainty and fast-paced decision-making, where the consequences of delays and errors may be vast and in some cases even fatal.

The ability to adapt to changes and to provide prompt response is regarded in the literature as flexibility and responsiveness (Bernardes and Hanna, 2009; Naim et al., 2010; Wilson and Platts, 2010). The incorporation of flexibility and responsiveness into the system is a complex task requiring high level of coordination. On the one hand, modern logistics operations are pursuing cost reduction and efficiency and, on the other hand, customers require responsiveness and flexibility. This duality of logistics objectives leads to the question of balancing the objectives via introduction of coordination mechanisms (Dubois et al., 2004).

A vast number of studies looked at achievement of flexibility and responsiveness in manufacturing and production environments, product design and service provision areas, but little attention is paid to the study of these phenomena in logistics systems (Barad and Sapir, 2003; Naim et al., 2010). Most of the existing studies are looking at a higher level of flexibility achievement on long-term and medium-term basis. These studies focus on market flexibility, supply chain flexibility (Garavelli, 2003; Dubois et al., 2004; Singh and Acharya, 2013), trust and cooperation. However, there is a gap in understanding of operational or short-term flexibility and responsiveness within logistics (Snoo et al., 2011).

By combining operational flexibility, logistics planning, coordination and control perspectives with information processing theory, in this paper we aim to get insights about the ways operational logistics flexibility and responsiveness are achieved in in complex logistics organizations.

In order to get better understanding of the phenomena in question, this paper explores the coordination practices from upstream logistics operations management in oil and gas industry. These logistics operations are hallmarked with a high need of transport flexibility and responsiveness in order to avoid enormous shortage costs, high demand uncertainty and a high volume of non-homogeneous cargo. In other words, a case from the oil and gas upstream logistics is a representative case for the purposes of our research.

The rest of the paper is organized as follows. In the second section, we review the literature on flexibility and responsiveness and its relation to coordination and information processing theory. The third section presents the research methodology and describes the data collection of the current study. In the fourth section, we present the case study of operational logistics planning from oil and gas upstream logistics. Next, we discuss analysis and implications from the case study. Finally, in the last section, we review the findings and draw conclusions.

2. THEORETICAL BACKGROUND

In order to study logistics system flexibility and responsiveness, we first review the literature defining flexibility and responsiveness. Thereafter, we provide an overview of the structures related to coordination mechanisms, planning and control. Finally, in the last part of this section we establish a link between flexibility and responsiveness requirements and organizational information processing design.

2.1. Flexibility and responsiveness

Flexibility research aims at understanding of the ways the systems adapt to changes and disruptions. A system is considered flexible if it is able to provide fast response to new constraints, demands and environmental changes in such a way that overall system's objectives can still be achieved effectively (Dubois et al., 2004; Wilson and Platt, 2010). As a multidimensional phenomenon, flexibility has a plethora of taxonomies and definitions discussed in the literature by Upton (1994), Barad and Sapir (2003), Bernardes and Hanna (2009) and Naim et al. (2010).

For better understanding of what is operational logistics flexibility and responsiveness, we review the classifications of logistics flexibility provided by Kress(1999) and Naim et al. (2010). Kress (1999) discusses military logistics flexibility. The author distinguishes between intrinsic and structural flexibilities. Where, the former is flexibility type associated with versatility of equipment and logistics products, and the latter type concerns the structural properties of logistics arrangement, processes and their execution. Intrinsic flexibility is long-term flexibility type. Structural flexibility has operational focus as it is related to processes. In other words, it is the ability of the company's internal processes to respond to changes between products, routes and transportation modes, the ability to incorporate changes in schedules and plans.

As mentioned earlier, the focus of the current study is operational flexibility – the short-term ability of the system to accommodate to changes. Therefore, we may state that intrinsic flexibility is not relevant for our research. In our study we rather focus on the operational

flexibility - structural flexibility of planning, coordination and control setup of logistics operations.

Another important characteristic of flexibility is its either proactive or reactive nature (Naim et al., 2010). Reactive flexibility focuses on dealing with actual changes, while proactive flexibility is a 'preplanned' ability to accommodate potential uncertainties. In other words, the nature of flexibility helps us to distinguish proactive operational flexibility from responsiveness. Responsiveness is a type of flexibility; which is related to the system's ability to provide timely response to some *stimuli* (disruptive event) (Bernardes and Hanna, 2009). Thus, responsiveness is a reactive flexibility of the system to provide fast response to changes in internal and external environment. Hence, in our study we focus on understanding the two dimensions of operational flexibility - its proactive operational flexibility and responsiveness.

2.2. Coordination, planning and control

Coordination has several definitions. In this paper we adopt Malone and Crowston's (1994, p. 90) definition: *"coordination is an act of managing interdependencies between activities performed to achieve a goal"*. Logistics operations are comprised of a series of interdependent activities, which are managed to provide a necessary level of service.

According to Heikkilä (2010) coordination mechanisms are composed of an information structure and a decision-making process. The information structure defines what information is obtained from the environment and how it is then processed and distributed. Decision-making process describes the way appropriate action is selected from the set of alternative solutions.

Frayret et al. (2004) coordination mechanisms into three major classes: programmed (coordination by plan), non-programmed (coordination during activities execution) and standardizations. Coordination by plan means formation of a predefined plan to coordinate *a priori* defined interdependent activities. Non-programmed coordination relies mainly on coordination by feedback. It is applicable when activities and their outcomes may not be specified in advance. As a result, coordination is done based on *ad hoc* information. Coordination by feedback implies information exchange during the execution of interdependent activities. Frayret et al. (2004) emphasize that coordination mechanisms selection depends on the characteristics of the environment.

2.3. Information processing view of flexible and responsive logistics organization

To gain better understanding of the link between flexibility and coordination mechanisms we turn to organizational information processing theory from Galbraith (1973).

2.3.1. Organizational information processing theory

Galbraith (1977) views organizations as information processing systems. The author articulates that coordination focuses on reduction of uncertainty in organizations. According to the author, uncertainty is the disconnection between the information required to perform a task and the information processed by organization. Galbraith (1974) states that the greater uncertainty and the task interdependence the greater amount of information should be processed among the decision makers in order to perform the task. In this vein, the task uncertainty shapes communication and control structures of the organization. Galbraith's organization information processing theory proposes some strategies of uncertainty mitigation (Figure 2.1).

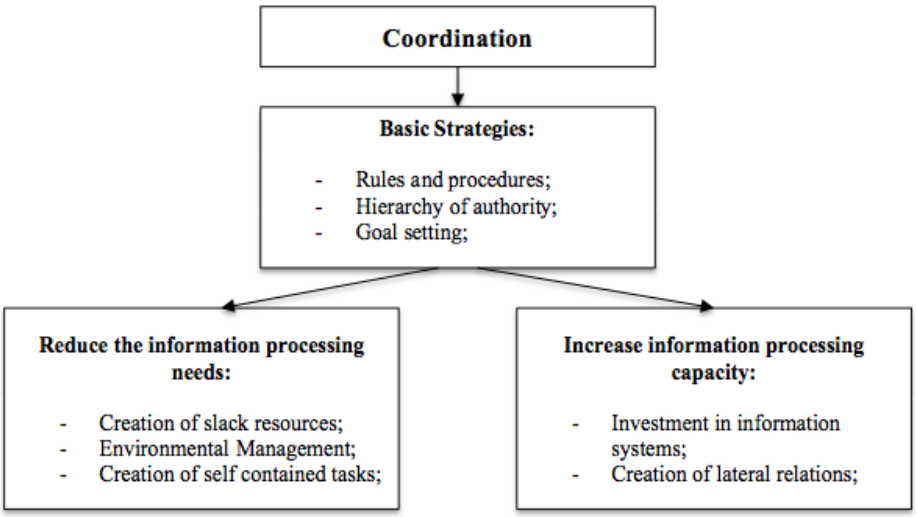

Figure 2.1. Galbraith's coordination framework (adopted from Galbraith, 1977)

According to Galbraith, application of the basic strategies, like rules and procedures, in highly unpredictable environments leads to overload of information processing system; which again results in undesirable disruptions, distortions and delays. Therefore, they should be complemented by other strategies.

To reduce the information processing requirements, organizations may add slack resources to their systems or create self-contained tasks. The use of slack resources is a common strategy perceived by managers, when there is lack of information processing capacity (Galbraith, 1977). Introduction of self-contained tasks implies switching from the functional task design to the one where each group has all the resources needed to perform a task at disposal; this system design reduces the need for information exchange. The second group of coordination mechanisms aims at facilitating information acquisition, distribution and processing in decision-making. These strategies are investment in information systems and creation of lateral relations. The former one implies introduction of information systems as a mechanism of dealing with uncertainty. While the latter one means introduction of liaison roles on the borders of interdependent activities, which communicate the relevant information. All the aforementioned strategies have their own costs; which should be considered during the selection of the strategy to be pursued by organization.

Aas and Wallace (2010) propose a model of logistics planning, which is similar to Galbraith's. Authors claim that logistics planning represents an information structure comprised of two elements, which complement each other. These elements are information availability and solving capability. Aas and Wallace (2010) argue that logistics planning is as a substitute to waste, slack resources and inefficiencies. Thus, we may state that coordination of logistics operations largely depends on its information processing capacity. Where information processing capacity is comprised of information and communication structure and decision making tools. Most of the logistics coordination literature focuses on studying mathematical tools and information systems, which provide data to these planning tools. However, we believe

that in some case the applicability of mathematical tools is insufficient and limited. This may be explained by existence of ambiguity and multiple interpretations of data and objectives in logistics coordination of activities, the so-called equivocality (Daft and Lengel, 1986). Therefore, organizations should establish information and communication structure mechanisms that allow clarification, and enactment rather than simple provision of large amounts of data and solving mathematical model.

2.3.2. Organization for flexibility and responsiveness

Grounded on the literature discussed in the previous sections, we will now discuss the information processing design for proactive operational flexibility and responsiveness. Based on Galbraith (1973), we claim that organizations may accommodate flexibility by either creation of slack resources or by increasing their information processing capacities. In the light of nowadays concerns about the cost and efficiency of the organizations, we omit the option of design with slack resources or self-contained tasks in this study. Thus, we focus on strategies related to increasing information processing capacity of the organizations in their design for flexibility. Therefore, we explore information-processing design in terms of characteristics of information and communication as well as decision-making structures.

Proactive flexibility is a 'preplanned' ability to accommodate potential changes. Barad and Sapir (2003) claim that from a flexibility point of view, a planning based approach has no flexibility. Planning is frequently based on optimization and the use of mathematical tools; which are justified in a deterministic environment, where no changes are expected (MacCarthy, 2006; Morikawa and Takahashi, 2007; Snoo et al., 2011). On the other hand, Van Wezel et al. (2007) claim that planning may be designed for flexibility but it should be supported with an appropriate information structure; which allows obtaining and consideration of all the changing parameters at the shop floor and the demand side. MacCarthy (2006) highlight that in order to plan in dynamic environments there is a need to reduce the planning and scheduling complexity. This may be achieved either via implementation of organizational remedies or by providing IT support to increase integration of data and problem solving capability. However, the authors emphasize that the "best practice" of complexity reduction is not the introduction of sophisticated problem solving software, but rather integration of highly qualified personnel and design of communication structures.

Thus, we may state that in order to provide proactive or "preplanned" operational flexibility, organizations should consider the following characteristics of information and communication structures and decision-making structures:

- Information and communications structures should be able to reduce the complexity of the planning operations by integration of the information about capacities and constraints from demand and capacity sides. This information should be obtained as close to real-time as possible. Thus, integrated information management tools as ERP systems play crucial role.
- Information and communication structures should support dynamic needs of planning communication and negotiation of changing goals and objectives that should be taken into account. In this settings the collaborative environments and collaborative information tools or communications structures may be implemented.
- Decision making structures should take into account the system perspective of the organization and consider activity interdependencies. For this purpose, the decision structure should have the attributes of decision centralization with mutual adjustment capability discussed by Frayret et al. (2004). The greater is the amount of unstructured

(not formalized) data to be taken into account in decision-making process, the higher is the role of humans and mutual adjustment in the planning process. As a result, the information structures used in such decision making process are more extensive.

Regarding the responsiveness, it is a timely measure of system's ability to be able to respond to the needs and disruptions. This requires a good feedback and action coordination structure, which ensures timely information acquisition, distribution and interpretation. The more activities are interdependent the higher is the need for a special structure with system overview in order to provide timely response. Therefore, we may conclude that responsive system requires tight exception communication structure, as well as the ability of the system to elaborate the exception information and provide timely response in terms of corrective actions.

- Dynamic system control is of particular importance in managing dynamic systems where action is required immediately if any unplanned event occurs (Kerstholt and Raaijmakers, 1997). Therefore, systems providing visibility are crucial components of the information structure to support flexibility and responsiveness in dynamic environment (Williams et al., 2013).
- Information and communication structures of the responsive systems should not only facilitate the capture and distribution of information about the current operations but also facilitate the system's ability to interpret such information and identify potential consequences of disruptive events (Allison et al. 2012). For this purposes organizations may apply the operational business intelligence and visualization tools.
- Decision making structure for responsiveness enhancement represents an "information hub" of integrated feedback structure (Morikawa and Takahashi, 2007), which very much relies on human expertise and ability of event handling and prioritization (Snoo et al., 2011).

In this section, we have identified the key characteristics information and decision-making structures, which are essential to provision and improvement of operational flexibility and responsiveness in the system. These characteristics are based on theoretical contributions and are rather general. Therefore, we find it relevant to explore the phenomenon further with empirical evidence.

3. RESEARCH OBJECTIVES AND METHODOLOGY

The main objective of our research is to gain insights about the ways the operational logistics flexibility and responsiveness are achieved in complex logistics organizations. After a careful literature review, we found it relevant to explore operational flexibility and responsiveness of the system from the point of view of information and communication and decision making structures. To provide a deeper understanding of the phenomena, we conducted an in-depth explorative case study in our research. Yin (2013) argues that explorative case study is applicable to the study of key events that have little theoretical background. Thus, the researcher may base its study on analysis and deep understanding of a single setting that provides the best representation of the phenomenon (2013).

For the purposes of our study, we explored the case of oil and gas upstream logistics operations coordination. Oil and gas upstream logistics faces high-level requirements for flexibility and responsiveness of offshore installations service. Oil and gas upstream logistics operations have to deal with high demand uncertainty, weather uncertainty, and high volume of non-homogeneous cargo. Moreover, the delays in offshore supply may lead to enormous costs of

the monetary, safety and environmental nature. In other words, a case from the oil and gas upstream logistics is a representative environment for the purposes of our research.

Data for this research endeavor were collected within a benchmark study of logistics operations between the Brazilian oil and gas company Petrobras and an oil and gas company operating at the Norwegian Continental Shelf. Main sources of data of this study are semi-structured interviews of key logistics personnel, observations during field visits, analysis of company internal documentation and reporting system. Incorporation of various data sources into our research has contributed to increase the validity of this study through data triangulation.

There were several data collection rounds in our study. During the first phase, our aim was to gain a full picture of logistics operations, their sequence and interdependencies. Therefore, we performed field visits and conducted several semi-structured interviews with key logistics departments' managers. The second phase of our research focused on logistics planning and coordination mechanisms. Thus, to gain a better insight about these subjects we conducted semi-structured interviews with key planning and coordination personnel and studied the internal documentation. All the interviews were recorded. During the third stage of the study, we analyzed the recordings and obtained documents. To ensure reliability and avoid potential bias in the study, in the last stage of our research we discussed and reviewed the findings with Petrobras' employees involved in operational logistics management.

Moreover, this study was conducted jointly with Petrobras's employees, which facilitated the access to data, its collection and helped to avoid bias in interpretation of the results.

4. CASE DESCRIPTION

4.1. Context of oil and gas upstream logistics

In this study, we explore flexibility achievement in upstream oil and gas supply chain. The upstream supply chain is comprised of all organizations, units and processes involved in provision of offshore exploration and production facilities with necessary supplies (Aas et al., 2008). The primary goal of the oil and gas upstream supply chain is to ensure continuous work of offshore exploration and production installations. The logistics system as a part of the upstream supply chain should provide continuous, reliable and flexible transport service to and from offshore units. The major focus of offshore logistics is to ensure that all supplies from onshore (and back-load from offshore) are served to the right installation (or back to the supply base) in requested quantity, quality and at the required time. This logistics system faces high requirements for flexibility and has to deal with a number of challenges and uncertainties.

Upstream oil and gas logistics system deals with transportation requests for heterogeneous cargo varying in size, volume, weight, value, safety requirements, etc. Moreover, the demand for this transportation services itself is a subject to uncertainty. In general, we can define two major types of customers with different types of demand; they are the demand of exploration units and the demand of fixed production units. The demand of fixed offshore production units is rather predictable, since it is associated with rather standard operations, where maintenance is preplanned and planning horizons are rather long. While on the contrary, the demand of exploration facilities faces multiple variations. Changes in their demand may arise due to some unforeseen circumstances in the exploration process. In general, oil and gas upstream logistics also has to adapt to weather uncertainties, which contribute to uncertainty in travelling times from onshore supply bases to offshore installations, or may even inhibit cargo receipt offshore due to safety restriction of offshore loading and unloading operations.

The shortage of materials supplies from onshore may result in high expenses. These shortage costs have several dimensions. First, the expenses may arise due to activity interruption because of missing supplies. Taking into consideration the daily rate of rig rental, which varies from 400,000 to 600,000 USD (IHS, 2015), the activity stop has very high hosts. Second, the lack of some parts may lead to breakdowns with high repairing costs and, in some extreme cases, and even lead to catastrophic safety and environmental consequences. Moreover, scheduling and rescheduling of certain offshore operations may be rather costly, for instance, in case of missing parts and tools for the planned maintenance operations, these operations should be rescheduled. The costs of such rescheduling are high and arise from many interdependent parts of complex maintenance operations. For instance, it may cause additional costs associated with personnel waiting for parts or idle time of costly rental equipment.

Due to the abovementioned reasons, oil and gas companies are continuously looking for the ways to increase the level of flexibility and responsiveness in their operations. However, in the ultimate years oil and gas companies are focusing not only on the flexibility but also on efficiency and costs reduction, which is especially relevant in the context of the current downturn in oil price. Therefore, oil and gas companies are searching for the ways of balancing the flexibility and responsiveness of the system and elimination of wastes and slack resources in the system.

In order to find intelligent ways of operation oil and gas industry has initiated Integrated Operations (IO) program. This program focuses on integration of people, organizations, work processes and information technology to achieve efficiency and effectiveness via smarter decisions (IO center; 2014). Under this program there were introduced several initiatives of so-called control rooms – collaborative environments, where operations are planned, coordinated and monitored. Introduction of such coordination unit for logistics operations management in Petrobras has triggered the current study.

4.2. The case company Petrobras

Petrobras is a public-private joint-stock company. The major stockholder of the company is the government of Brazil. Petrobras was founded in 1953, and since then, it has become a leader in the Brazilian oil industry. Ultimately, Petrobras has expanded its operations aiming to become the top five integrated energy company in the world by 2030.

One of the key milestones in the recent history of Petrobras was the oil discovery in Pre-salt layer. This discovery created an exciting scenario for the company in multiple aspects. From one side, the contribution from Pre-salt area is expected to double the proven reserves of the company (Campos Lima and Tenorio Gomes, 2013). From the other side, the development of Pre-salt area means many challenges Petrobras has to deal with. Among them are logistics challenges as, e.g., the distances to onshore terminals increase. The logistics infrastructure and organization should be able to provide the necessary level of service in order to support this future expansion at a minimal level of expense.

4.3. Upstream oil and gas logistics operations at Petrobras

The major process milestones of the physical flow of materials in upstream logistics operations are presented in Figure 4.1. We may determine two types of flows. The distinguishing feature is the structure of the flow to the supply base. In the first case, cargo is directly transported to the supply base from the suppliers or subcontractors. In the second case, the cargo is handled via Petrobras' internal handling process. In the current research paper, we limited the scope of

the study to the internal chain of activities, which includes the processes highlighted with grey background.

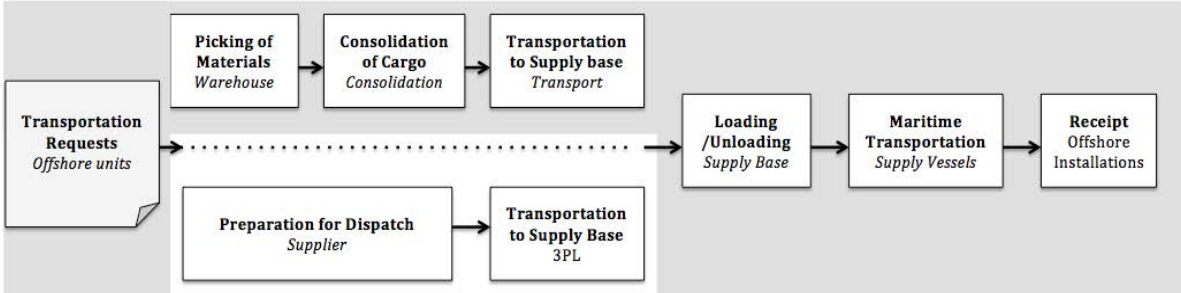

Figure 4.1. Upstream oil and gas logistics process of transportation request handling

Upstream logistics consists of multiple departments (in italic) performing various logistics tasks. The major physical process steps are preparation of materials for dispatch, consolidation, transportation of materials to a supply base, loading of cargo on a vessel, maritime transportation by the supply vessel, receipt of cargo offshore. In this research, we omit backload-handling operations. The physical flow operations are complemented with planning of the vessel load, which is conducted by maritime department. This department performs planning and allocation of supply vessel deck capacity to transportation requests. As we have discussed earlier the activities performed by logistics operations departments are interdependent and as a result require high level of coordination. A separate unit called Integrated Management of Operations Center (GIOp in Portuguese) performs this operational coordination. In the next section, we discuss the major activities performed by the above-mentioned coordination center.

4.4. Logistics planning, coordination and control center in upstream oil and gas logistics at Petrobras

For the purposes of coordination of activities at an operational level, and provision of flexibility in the system, Petrobras has integrated its logistics planning and coordination functions into a single unit, referred to as GIOp. This unit consists of around 82 employees: whose roles are subdivided into: GIOp planners on the customer side, GIOp integrated view planners and regional logistics representatives (Figure 4.2).

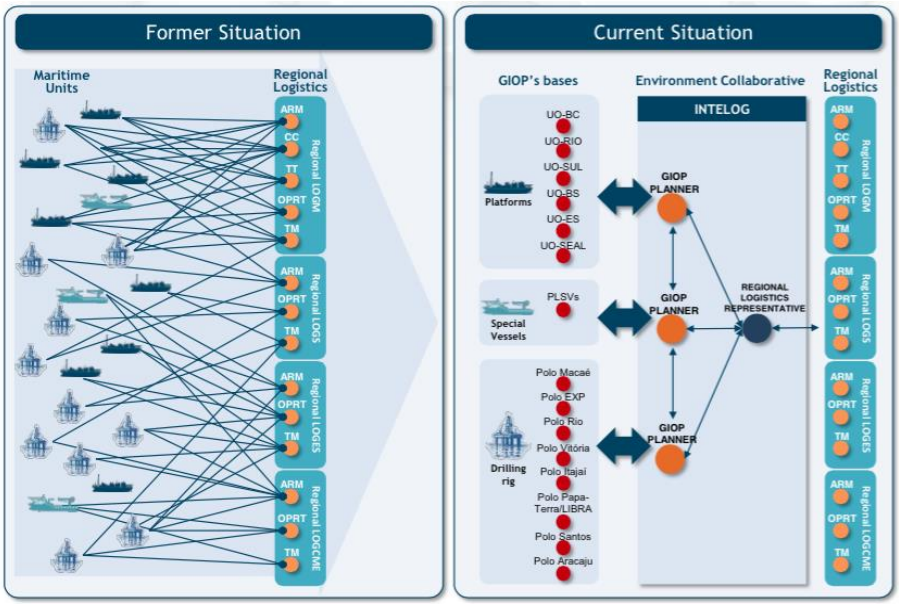

Figure 4.2. Management of logistics operations in Petrobras before and after the introduction of GIOp (Source: Pinho, 2015)

The functions performed by this unit may be subdivided into two levels: (i) logistics activities planning and prioritization, (ii) monitoring and control of logistics activities execution.

During logistics activities planning GIOp plays a role of integration and collaboration hub in the complex and iterative process of planning. First, GIOp planners from the customer side collect and correct the transportation requests according to the current needs of installations. Then, this total demand is disaggregated by planned supply vessel departures and based on backward planning of logistical operations when the first variant of the operational plan is developed. Next, this first version of the operational plan is distributed to regional representatives of logistics operations departments, which based on their current knowledge of capacity restrictions and knowledge of workload for demand handling identify the demand workload that may be handled on each day. In other words, each logistics department states the part of proposed demand plan they may handle on daily basis. Applying this technique helps Petrobras to deal with variability in capacity requirements of heterogeneous cargo and the dynamics of available capacity. Next GIOp collects all the data on the part of the demand to be handled by each logistics operations department, and based on these data determines the bottleneck capacity of logistics operations. After identification of the bottleneck capacity, GIOp has to treat the demand, which exceeds it. At this step GIOp planners on customer side start the process of prioritization of transportation requests and negotiations with offshore installations. The result of these planning activities is a new version of the daily operations plan for each logistics department.

The second function of GIOp is aimed at monitoring and control of execution of logistics operations. GIOp's regional logistics representatives are continuously monitoring the progress of the transportation requests handling by the different parts of the logistics organizations. The progress is tracked on the latest request fulfillment time, which allows identifying the late jobs early in the transportation request's handling. GIOp personnel continuously monitor the

progress with the help of monitoring and visualization technology. In figure 4.3, you may see a picture of this visualization tool in in GIOp control room.

Figure 4.3. Process monitoring visualization tool (Source: Pinho, 2015)

If any delay or other kind of disruptive event occurs, GIOp personnel evaluate its criticality and consequences as well as potential event handling options, and then establish corrective actions. Manager of GIOp highlights that collaborative environment as well as knowledge and expertise of GIOp are key elements in success of the monitoring and control environment of GIOp.

5. CASE ANALYSIS, DISCUSSION AND IMPLICATIONS

5.1. Case analysis

In this part of the paper, we analyze the case in respect to the theoretical foundations of the study. First, we find it relevant to discuss information and communication structure. Then we turn to analysis of the particular features of the decision structure of the planning and monitoring activities implemented at Petrobras.

In our literature review, presented in Section 2 of the current paper, we accentuate that flexibility and responsiveness add complexity to the system. To deal with such complexity organization should establish an appropriate information and communication structure. Petrobras approached this complexity reduction in three ways discussed below:

- Structural complexity of information flow was simplified with the introduction of GIOp as a coordination and information hub, as it has reduced the number of contact points. In figure 4.2, you may notice that prior to introduction of GIOp the information and communication structure of upstream logistics at Petrobras was rather complex. With introduction of GIOp the number of communication links was reduced from n*(n-1) to 2n (assuming bidirectional information flow). Thus, GIOp's communication structure significantly improves the information capacity and helps to reduce the information overload in the organization (Galbraith, 1973).
- Iterative process of collaborative operations planning helps to reduce equivocality with regard to demand, variable capacity constraints and priorities (Frayret et al., 2004; Snoo, 2011). As a result, such approach helps to reduce the number of exceptions at later

stages of process execution. In other words, collaborative planning helps leads to reduction of information processing needs and equivocality in operations (Daft and Lengel, 1986).

- Collaborative environment design of monitoring and event handling system cause decrease in information structure overload of exception and corrective action communication (Galbraith, 1973; MacCarthy, 2006; Snoo, 2011).

In relation to decision-making structure we may identify two major decision types involved in coordination of upstream logistics. They are related to two types of operational flexibility that we focus on. The first one is related to proactive operational flexibility, which is associated with decision making at operational planning stage. The second one refers to the decision-making during the response to the disruptive events, and selection of alternatives that minimize the consequences such events.

- Planning of transportation requests handling has centralized structure in GIOp, this structure allows the system view and consideration of interdependencies between activities. Even though GIOp planning has business intelligence tool used for transportation requests disaggregation by vessel departures and backward scheduling, this IT-solution is not the key component of logistics planning process. Actually, logistics planning process is rather human extensive. Humans are involved in bottleneck identification and adjustment of transportation requests demand via negotiation of priorities.
- Exception handling decision-making, similar to planning, has a centralized structure. This design feature contributes to creation of collaborative environment in event handling. Collaborative event handling improves and speeds up the decision making process, this environment was illustrated with figure 4.3.

It is important to mention that Petrobras management claims that introduction of GIOp has improved the responsiveness and flexibility of upstream logistics operations. GIOp helped the logistics organization to deal with disruptions and provide a better service to installations. Thus, company management claims that after GIOp implementation, Petrobras has achieved 80% reduction of time the exploration rigs were stopped due to logistics issues (Pinho, 2015).

5.2. Discussion and Implications

Ability to respond and adapt quickly to internal and external changes plays crucial role in companies. Operational flexibility is even more vital for fast response organizations, which have to deal with a high level of uncertainty under the condition of costly and sometimes even fatal consequences of missed service or delays (Faraj and Xiao, 2006). Examples of fast response organizations are hospitals, firefighting operations, natural disaster recovery and other emergency operations. We should admit that the abovementioned examples are extreme cases of fast response organizations. However, some of the businesses due to their nature face similar conditions. The case study we explored in this paper demonstrates that oil and gas upstream logistics organization operates in the environment, which is similar to fast response organization. Thus, oil and gas upstream logistics requires significant level of flexibility and responsiveness, in order to prevent disruptions or delays, which may result in high monetary, safety and environment costs.

We have found that, in order to deal with proactive operational flexibility and responsiveness, relevant coordination mechanisms should be selected. In other words, in order to design organizations for operational flexibility, one should consider special features of information

and communication and decision-making structures. In order to deal with uncertainty and provide timely response to changes, these structures should empower visibility of operations and collaboration during planning and event handling of logistics operations.

While, in most of the literature, planning is associated with rather rigid mathematical models, in dynamic environments these models are rarely applied (MacCarthy, 2006; Snoo, 2011). This fact may be explained by the lack of formalized inputs, wide diversity of dynamic parameters and multiple objectives that should be taken into account in planning. Instead of planning with mathematical models the companies tend to use humans for planning activities. Proactive operational flexibility is achieved via *ad hoc* planning arrangements, which rely on mutual adjustment of plans based on continuous feedback from the operations. Our case study has revealed that integration of information and decision making together with a collaborative environment play a crucial role in operations planning. Introduction of a planning and coordination hub helps to reduce the number of interactions between units and improves flexibility of operational planning.

In the design of responsiveness in organizations the companies should focus on development of the system that allow caption and communication of disruptive events. Therefore, essential part of responsive organization is monitoring system, which reflects the current situation and progress on the shop floor, where activities are performed. The necessity of monitoring and visibility is also highlighted by emergency relief literature (Holguín-Veras, 2007). However, monitoring is not enough to achieve system responsiveness. It should be complemented with visualization and collaborative decision-making structure of event handling. Collaborative decision-making allows assessment of system-wide consequences of disruptions and delays and speed up the process of event handling.

While the technology is not the major element of the abovementioned structures, it is still their important component, which supports planning and response activities. We should also admit that collaborative environment is built based on highly integrated information systems.

To conclude, we may state that collaborative environment together with integrated planning and control are the key characteristics of information processing structure for operational flexibility and responsiveness.

6. CONCLUSIONS

Nowadays, ability to adapt to changes in the environment is a vital characteristic of organizations. Design of organization for flexibility and responsiveness is a complex phenomenon, which requires better understanding and further investigation. In this paper, we applied the constructs from information processing theory and coordination theory in order to investigate the ways in which operational flexibility and responsiveness are achieved in complex environments facing high level of uncertainty.

Our study suggests that flexibility and responsiveness require appropriate information, communication and decision-making structures. The further insight of these structures was gained via in-depth case study of logistics operations planning and control in oil and gas upstream supply chain. The study reveals that collaborative environment together with integrated planning and control are the key characteristics of information processing and decision-making structure for operational flexibility and responsiveness.

The findings from this study advance the knowledge of operational logistics flexibility and coordination. Moreover, results from this research contribute to the organizational design

literature. The prosed organizational design characteristics will aid managers in development of flexible and responsive logistics organization. This is especially relevant for companies operating under conditions similar to fast response organizations, where the consequences of being inflexible are enormous.

This study has limitations, which should be addressed by the future research. Our research results are based on a single case study, which seriously limits the generalization of the results. The relevance of the findings from the study should be explored further in other industrial settings and on a bigger scale (using several case studies or surveys). Moreover, to gain a better understanding of the collaborative environment, there is a need for further investigation of the role of humans in planning and coordination of operations.

Another limitation of this research is that the discussed coordination system was implemented to coordinate the operations on intra-organizational level. However, in many cases companies need to create flexibility and responsiveness on inter-organizational level in the supply chain. Therefore, the future research should investigate the applicability of the findings in the inter-organizational settings, where the interest of various companies should be taken into account.

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Online grocery retailing in Austria
A distribution planning strategy for multi-channel development

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ABSTRACT

Purpose
The uncertain market in online grocery retailing as well as the unclear ambivalence whether traditional distribution networks can handle e-grocery activities are two aspects of high significance. Given this challenging setting, the purpose of the paper is to develop a distribution planning approach for identifying capacity utilisation in online retail logistics distribution based on expected online sales potential.

Design/methodology/approach
As no defined regional experiences from market competition can be referenced and no insights be derived from the past, a complementary approach of combining statistical data and scenario analysis with consumer focus detection and field testing has been used.

Findings
A specific distribution planning approach under uncertain market development enabled to identify sales potentials and to clarify logistics' scalability (capacity utilisation, locations planning, order handling, interface to service provider, etc.).

Research limitations/implications
A central implication in course of the underlying research is the context-specific analysis for an Austrian grocery retailer, which limits the derived findings to a non-general validity.

Practical implications
The developed strategy and its aspects led to an applied concept and strategic cooperation between the involved retailer and a service provider in Austria.

Original/value
As solid indications in setting up distribution concepts for online grocery retailing lack in Austria, a relevant strategy for identifying distribution strategy conditions has been a distinctive new type of managing uncertainty in e-commerce. Because of no available regional experiences or past insights, the developed master-distribution-planning approach helped an Austrian grocery retailer to build up a supply chain strategy in e-commerce.

Keywords: Grocery retailing, e-commerce, distribution planning, uncertainty, supply chain strategy

1. INTRODUCTION

Most recently the grocery retail sector experienced, like almost all other consumer industries, challenging times. Consumer reluctance and, above all, markets dominated by price competition squeeze revenues and margins for retailers and require new strategies. In this context, the B2C online retail segment appears as solid as a rock and seems to offer an innovative solution for the grocery industry as well. The general trend of online shopping seems almost unbroken. Nearly a quarter of all customers who later shop in-store have previously gathered information on the products online. Consumers are more and more moving between the various channels. It begins to emerge that the most successful retailers are those who have established multi-channel strategies. This also means for grocery businesses that multi-channel can add value to operations, can allow consumers doing "channel-hopping" and can realize the combination of traditional in-store shopping and e-commerce (Heinemann, 2010).

Digital web shops in e-commerce and traditional (i.e. brick-and-mortar) stores each have unique features. The internet substantially reduces search costs, grants easy access to product and price information and facilitates product comparison. Online shopping involves no travel, product carrying or restrictions on shopping hours. It offers great accessibility, saves time and generates convenience for consumers. In return, online shopping does not grant physical examination of products (e.g. feel or touch), is without interpersonal communication and often incurs additional shipping or processing costs (Grewal *et al.*, 2004). Consumers may use the two channels differently. Some consumers may use traditional grocery stores as the primary shopping channel and the online-shop as a supplementary channel, whereas others may follow the reverse pattern. Consequently, the same consumers may exhibit different behaviors when shopping across online and offline channels. Therefore, it is important to understand how the same consumers behave at the two channels and how to link the consumer touch points on both ends (Chu *et al.*, 2010).

In grocery retail practice, there is already a wide awareness that e-commerce-related issues completely differ from traditional in-store grocery shopping. Hence, the online–offline differences are larger for food products than for non-food products. Categories such as books or clothing have proven to be suitable and seem to be recognized for typical online shopping activities. At first sight, they are more ideally suited than grocery products – which is evident due to the share of online-ordered and delivered grocery products compared to non-food categories. But, although online revenues only account for a small fraction of the grocery industry, many conventional grocery businesses do have online operations additional to their physical stores or are setting up strategies for developing virtual food retail (Boyer and Hult, 2005). This is also the case in Austria. Briefly, the online retailing sector in Austria can currently best be described with the word "dynamic". Both the supply side (retailers) and demand side (consumers) have developed strongly in the last 7 years. This applies both to the number of online stores (including their sales figures), as well as to the number of online shoppers and their online expenses on grocery products (Gittenberger and Vogl, 2014).

However the habits of domestic online grocery shoppers are still not obvious, their perceptions are previously unknown and therefore difficult to estimate. In addition to that, the unclear ambivalence whether traditional distribution networks can handle online grocery business (without fundamental modification) or not, is an aspect of high significance (Wyman *et al.*, 2013).

Studies on online grocery retailing show that 4% of Austrians regularly and repeatedly bought food products online (Gittenberger & Vogl, 2014). This represents a market volume of about 70 million euros a year. In their study, Nielsen Company (2012) refer to a growth rate of 7% per year in the period 2012-2016 and the overall balance of the grocery retail sector in Austria. This forecast would result in an expected total value of 92 million euros for the Austrian grocery online segment. Compared to Germany, 5% of consumers buy food repeatedly online which results in an online grocery market of about 370 million euros in total annually. The online share in Germany is about at the same level as in Austria (0.3% of the total retail business). This share is slightly higher in Switzerland (0.7%) resulting in a total market volume of 360 million Swiss francs (295 million euros) (Nielsen Company Study, 2012).

The aim of this paper is to develop a planning strategy that considers **indefinite online grocery sales potentials** and **logistics network processing constraints** in terms of last-mile distribution. As there are no best practice cases in Austria, the underlying research is aligned to answer, what strategic perspectives are relevant to support and realize multi-channel grocery development – in a hands-on planning approach.

2. Methodology and Background

As we explore unknown territory in the domestic online grocery market Austria (no defined regional experiences from market competition and no insights to be derived from the past) a complementary approach of combining statistical data & scenario analysis with consumer focus detection & field testing, is been used. A hands-on planning approach – motivated from an appropriate applied research project background – should consider utilization aspects and distribution framework conditions based on expected sales potentials in domestic online grocery.

Tackling the purpose of this applied research the following methodical steps were followed:

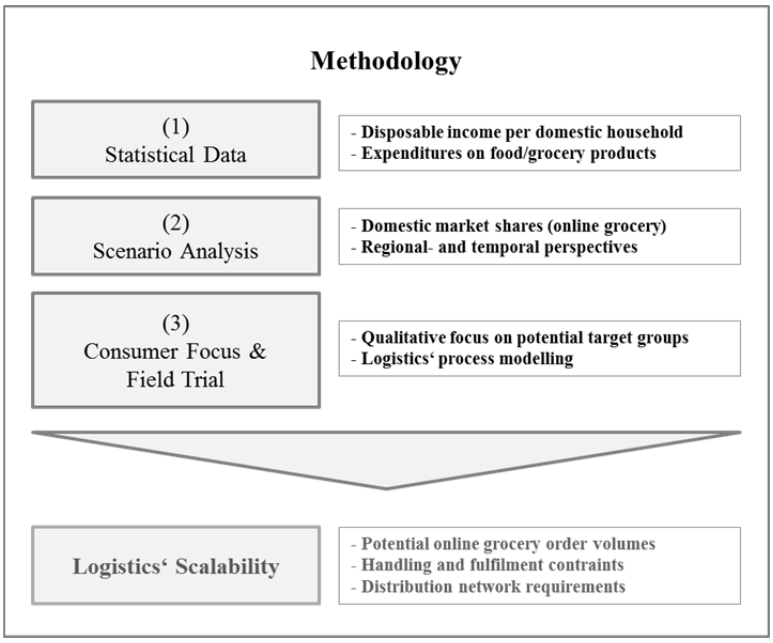

Figure 1 - Methodical steps in underlying research

In short, the methodology comprises

(1) a “top down approach” using data such as disposable income (average value for every Austrian postal code) and percentile spending on the relevant shopping basket,
(2) a scenario analysis for varying expected market share, future development of online grocery retailing and average shopping basket (i.e. consumer ticket) as well as
(3) a “bottom up approach” with consumer focus groups and process handling tests for both identifying shopper perceptions and examining fulfilment performance.

On the basis of *statistical data* (gathered from different studies and freely-available statistics) the current market potential for grocery online in Austria has been calculated. It should reflect the **potential order volume** (based on available income of over 3.4 million households in Austria) on the one hand and the **geographic allocation** (about 2.100 postal code levels – relevant in terms of the distribution network) on the other hand. As previously mentioned, there is sufficiently no meaningful data on the market potential for online grocery in Austria. In a first step, therefore, the available statistical data has been collected and a followed quantitative calculation, on the level of

- disposable income per domestic household,
- expenditures on food / grocery products and on (consumer behavior)
- share online or grocery-online (online user behavior).

In detail, the market potential which corresponds to the revenue potential and the number of orders originated online, was calculated using the following information and data:

- Postal code, number of households and purchasing power based on specific data (*GfK, RegioGraph, 2013*)
- Disposable income in Austria (*Statistik Austria, household income 2012*)
- Expenses for the relevant shopping basket [food, beverages, toiletries] (*Statistik Austria, consumption expenses 2011*)
- E-Grocery share: according to various statistics and studies (*e.g. AT.Kearney, Forrester*)
- Average shopping basket (consumer ticket) – reference value taken from Austria’s major grocery player and complemented through discussion with experts on prospects regarding shopping basket amounts.

This calculation allows the exemplification of the turnover and the number of parcels to be realized along the online grocery channel for 2015. The data primarily served as a starting point for the scenarios development.

The *scenario analysis* serves to derive three scenarios for representing the future development of the grocery online share until 2020 (including attainable market share of one specific grocery retailer). This approach reveals theoretical possible sales and order volumes per year within the respective scenarios. Scenario characteristics (e.g. market share) are generated from a series of expert-workshops with the general management and strategic decision makers of the focal Austrian grocery retailer.

In order to complement the quantitative analysis, *focus group* interviews with potential consumer groups are conducted. Twenty in-depth focus interviews with random selected people related to the interdisciplinary team of researchers and involved retail managers. An applied *field trial* (enfolding twenty-six used-cases) enables the research team to test and evaluate developed processes and logistical infrastructure invested for home delivery of grocery orders.

All the collected information and data serve as a foundation for deducing aspects in terms of the logistical scalability of a specific online grocery business model ("e-grocery).

Mentioned elements combine a planning approach where a new set of service in the online grocery segment can be addressed. This approach promises assistance to consider and introduce operational necessities for new business modelling with incorporating relevant fundamentals for serving this field of business. Before entering the findings section of the developed distribution planning approach, the authors refer to the thematic framework that underlies this case research.

3. THEMATIC SCOPE

3.1. Domestic market development: online vs. traditional shopping

In recent years the described dynamics in online grocery retailing in Austria, according to study results by SME Research Austria, are particularly triggered from traditional in-store grocery business. While mail order businesses show a significant increase in their online segment (as of total sales), the highest turnover in online retailing accounts for traditional grocery retailing (Gittenberger & Vogl, 2014). This is partly because on the one hand, more and more traditional grocery businesses work on dual sales and distribution strategies (i.e. multi-channel-strategy) and on the other hand on increasingly higher sales figures in online shops (i.e. e-commerce development). A significant step-change is undergoing in the Austrian online grocery retailing: a structural change that is characterized by a rapid increase in online sales of traditional retailers (starting from a fairly low level). For the domestic grocery retail, the Internet plays an increasingly important role – both for the presentation and sale of grocery products. Almost 20% of retailers sell their products online – via own online shops or through online platforms. The multi-channel strategies where the physical retail stores are strategically combined with online shops are on the rise. A total 65% of online retail sales account for the domestic Internet retailers and their online stores (25% on the established mail order business and 10% on the pure-players).

The comparison of the supply side (retailers) and the demand side (consumers) – despite dynamic development on both sides – even shows level differences. Whereas 57% of Austrians buy products online, only 19% of retail businesses offer their range of products on the Internet. Further comparing the *gross annual sales in the domestic online retailing sector* (2.9 billion euros in 2013, incl. VAT) with the *total amount of Austrians' online purchases* (5.9 billion euros), a clear backlog is recognizable. In this view, the domestic retail businesses thus cover only half of national online expenses. The remaining half drains off towards the international retail sector as well original brand manufacturers abroad. A situation that remained almost constant in recent years.

The study finally suggests, that future developments multi-channel through online retailing will be mainly influenced by the development of micro-enterprises (in the online segment) and particularly by increasing online grocery offers (Gittenberger & Vogl, 2014).

3.2. Online grocery distribution

In general, the interlinkage between existing and new mentioned processes in retailing (i.e. e-commerce solutions) is of high priority in terms of cost- and time-efficiency. With regard to existing processes in traditional (brick-and-mortar) retailing, several linked requirements and potentials of distribution concepts for handling e-commerce need to be considered. The aim

for developing facts for a common process for distribution processes joining both, traditional grocery and e-grocery streams (Schögel *et al.*, 2004). So, in terms of considering e-commerce demands as a *new value stream in grocery retailing*, requirements for adapting existing or incorporating new processes have two grievances: on the one hand, (i) relevant process options, in connection to existing distribution in grocery retailing, need to be identified; (ii) the criteria on the retailer's and the end consumer's side also need to be given strong consideration (Schramm-Klein and Morschett, 2005; Ehrlich, 2011).

The central aspects in strategic distribution logistics management structures, to handle online retailing activities, refer to inventory strategies and to transport processes. In terms of online **order-picking processes** (related to inventory management), two main options can be distinguished:

- warehouse-picking, order processing at a dedicated location (e.g. within a regional warehouse or a dedicated "dark-store") or
- in-store-picking, at the point of sale (e.g. in an established physical grocery retail store with appropriate resources and space requirements).

Regarding **e-grocery distribution transport processes**, three main strategies are commonly seen in practice:

A first option represents a *home delivery from a local grocery retail warehouse (dedicated "dark-store")*, where orders can be prepared (warehouse-picking) for home delivery and distributed through existing network infrastructure (i.e. lorries, routes). Ordered products are delivered to the consumers' home address (i.e. place of consumption) using light goods vehicles and optimized routing conducted by logistics service providers or through the retailers' own fleet of vehicles. This option is of very sophisticated character, as traditional processes, especially in the warehouse-picking processes, are heavily influenced and restrictive constraints need to be considered when conducting own fleet delivery.

Another option is the *home delivery from a dedicated physical grocery retail store*, where orders are prepared after picking and packing processes (in-store-picking). The ordered products are then either (i) directly delivered at the consumer's home address or (ii) delivered to a local distribution location (operated by a logistics service provider partner). In this option, the handling processes between the picking and transferring into the last mile delivery process is very crucial. A co-operation with a professional service provider can be decisive.

The third option displays the *distribution through specific reception points* (temperature-controlled depots) that are located near the place of consumption. Ordered goods are picked up by the consumer at dedicated local pick-up areas (by avoiding queues, shopping and waiting times at the store). In the described self-pick-up process, (especially for stores located in urban areas with good public transport accessibility) there are more transport modes available for consumers during their assimilated individual trips for respective shopping purposes (Durand and Gonzales-Feliu, 2012).

From an e-grocery perspective, the home delivery service stands for the distribution logistics element within the whole fulfillment process in online grocery consumer transactions. As parcels and small packages need to be distributed, online retail requires the cost-efficient and customer-oriented design of home delivery processing. Functionality and reliability regarding process quality of home delivery is crucial for any online business models and a key success factor (Ehmke and Mattfeld, 2012).

3.3. Last-mile challenges and logistics strategies

As mentioned, the mode of delivery and distribution emerged as a "last mile issue" in the literature (Punakivi *et al.*, 2001) and appears to be the crucial barrier when developing e-grocery strategies towards a feasible business model (Boyer and Hult, 2005; Keh and Shieh, 2001). The differences in this matter of how to act in the last-mile are evident. Either customers can pick up their orders from dedicated local retail stores, or the online ordered goods are distributed to the customer's home through home delivery services conducted by additional transport service streams. The literature suggests that direct home delivery of online grocery orders is gradually becoming more interesting. Consumer groups of today (i.e. busy professionals, passionate online shoppers, families, etc.) steady require that kind of services and want to be understood in their needs and behavior. According to Liao et al. (2010), "the customer-orientation of the home delivery business model is the main trend of development in online shopping at the present and in the future (Liao *et al.*, 2010)."

Unfortunately, little research investigates how customers perceive attended or unattended delivery models. The consumers' demand for e-grocery, with a *focus on unattended delivery* may be influenced due to customer characteristics (e.g. age and gender) or other variables such as local grocery store distance, shopping duration and shopping pleasure (Goethals *et al.*, 2012).

Those implications on the currently rather unknown grocery shopping characteristics leaves several questions unanswered so far: What number of customers is imaginable from the start of a "virtual retaility"-strategy? Are customers ready to accept additional costs for home delivery, and do they accept e-grocery services without a home delivery option? What perceptions for the retailer are to consider in this set of unknown issues?

A defined logistics network to serve the last mile issue is considered to be more efficient than a business model based on a concept where the grocery consumers take the "cost of the last mile". The grocery consumers of today will not be set to be changed in terms of their future shopping habits – from traditional shopping towards a substantial online share. Consumers certainly will notice that shopping is not always fun and home delivery services entirely free of charge. But it is the logistics strategy to begin with. In case of a capable distribution network for home deliveries, consumers are willing to pay for the service (Yrjölä, 2001).

The following approach enfolds strategic features to address these questions, and identifies a planning structure to explore crucial aspects for a specific e-grocery strategy in Austria.

4. Results

4.1. Data and scenario analysis based on domestic market

The data analysis resulted in (i) a *scale of potential volumes of the average shopping basket* (i.e. consumer ticket) for regional online grocery orders and in (ii) a *regional, geographical allocation of potential orders* (based on postal code) for constituting the distribution network demand. Captured average value in e-grocery – displayed according to household statistics – is at 39.76 euros (ranging from 21.20 to 139.68 among households in over 2.100 postal code areas). The taken geographical allocation (i.e. matching average online shopping basket volumes with the region) serves as a basis for deciding on distribution network strategies.

In the scenario analysis, the (i) *market share of the domestic retailer* and the (ii) *online share in the relevant testing and target regions* (i.e. national implementation areas) were taken into

account. A distinction was made between urban and rural areas. The reason for this is, that in urban areas a “same-day-delivery”-service (i.e. order until 12 am – delivery time windows from 6 to 9 pm on the same day) is offered. This type of service is an attractive offer for consumers in dedicated densely populated urban areas. In the underlying e-grocery development, the rural areas experience the “next-day”-service exclusively (i.e. one working day after the online order is the respective delivery day).

The process of consideration of the market share is based on an expert workshop with involved general management and strategic decision makers, in which the market share of the focal retailer was estimated for the online grocery segment in the domestic (national) market. In addition, a *temporal perspective* has been integrated in order to assess the development of the online share of the relevant market for defining and developing the three following scenarios:

“Worst-case”-scenario: the grocery online share stagnates at 0.77%; there is no growth above market growth; the e-grocery offer of the retailer will certainly be noticed and tried at times, but is not established permanently; the market share is increasing by 2.0 percentage points per year.

“Trend”-scenario: studies assume a growth in the grocery online share of up to 10% per year – this trend is assumed in this scenario; further, the retailer achieves a market share of 10% in 2015; the annual growth is 2.0 percentage points.

“Best-case”-scenario: the grocery online share increases to 6%; the retailer uses the first mover advantage, is positioned as a market leader with a market share of 15% in 2015 and records an annual increase in market share by 3.0 percentage points until 2020.

The presented scenario analysis and figures refer to expectable sales and order volumes (identified in number of parcels) on a weekly, monthly and yearly basis. The following table (Table 1) presents the summarizing items in the three scenarios:

Table 1 - Domestic e-grocery scenario details

Scenario	Market share “national e-grocery”	Market share “domestic retailer”	Average shopping basket of e-grocery order	No of parcels for e-grocery order
Worst-case	stagnates at 0.77%	5% + 2 percentage points p.a.	20 Euros	1
Trend-case	increases by 10% p.a.	10% + 2 percentage points p.a.	40 Euros	1,5
Best-case	increases by 6% until 2020	15% + 3 percentage points p.a.	60 Euros	2

The estimated online shopping basket varies between the scenarios. Derived from experiences within the field trial phase (i.e. different grocery orders from traditional retail stores were packed into parcels) the *average number of parcels* per order has been identified (a basket of 20 euros order volume equals one parcel, 2 parcels are assumed to equal 60 euros in average).

A first assessment on the domestic online grocery market has been shown both with respect to (i) potential quantities and value streams (number of parcels or sales at the federal state/postal code level – geographical allocation) and according to (ii) elaborated scenarios.

Sales and number of parcels per week have been calculated for the time span 2015 to 2020. The following figure (Figure 2) shows the results:

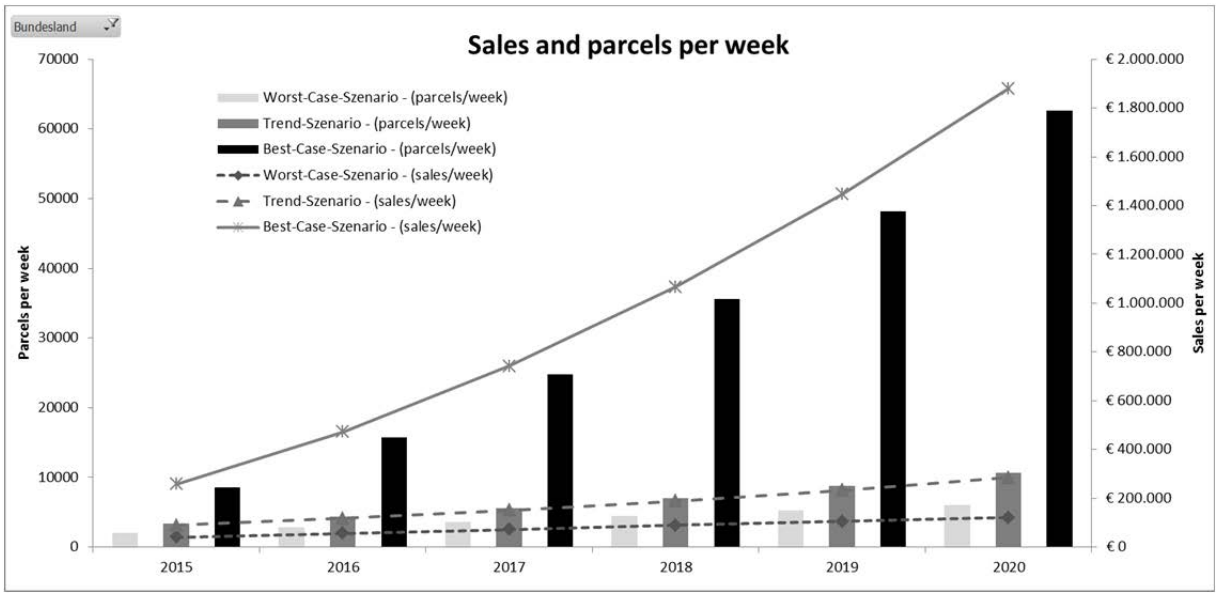

Figure 2 - Sales and number of parcels in e-grocery scenarios

The results – in sales and parcels per week – are shown in the figure above; the lines show the sales development for a worst-case, a trend- and a best-case scenario; the bars display the amount of parcels in each of the different scenario. The use of two data bases allowed a clear pursuing of goals in the analysis phase and created the comprehensive and practical base for the following elements in the distribution planning strategy.

4.2. Consumer focus and field testing results

As mentioned in chapter 2, four potential target groups for the domestic e-grocery were identified and surveyed regarding (i) personal shopping behavior in general, (ii) online behavior and selection preferences in relation to fulfilment of grocery demand as well as regarding (iii) expected quality aspects of logistics fulfillment processes. The gathered data allowed broad qualitative insights on market potentials for online grocery. The focus interview phase consisted of five interviewees from each target group (described in Figure 3):

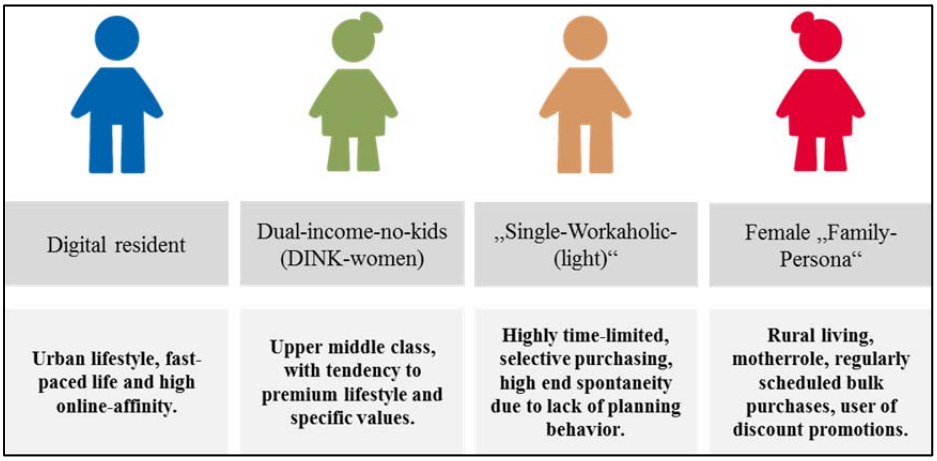

Figure 3 - Consumer focus groups

For many interviewees, “time” as a resource is crucial for joy, pleasure and inspiration in the shopping process. When there is little time available (and this was obviously the most prevalent condition identified), then grocery shopping is a real stress-test. Skepticism regarding e-grocery mainly concerns (i) the non-appearance of a real shopping experience in-store, (ii) the considerable lack of surprise effects or spontaneous purchases, and even (iii) missing positive emotions in the decision-making process at the shelves.

Overall, the Internet is considered as an important part of respondents’ everyday lives. The interviewees use the Web distinctively and show apparent affinity to shop online. In the specific case of e-grocery services, a third of respondents can imagine to order grocery products online. The majority limits the range of products: first and foremost, respondents would order durable products as well as toiletries. At a first glance there is skepticism regarding the order and delivery of fresh products, dairy products, fruits, vegetables etc. In this context, high quality in the handling and delivery process is obligatory for respondents.

For capturing the required *logistics process quality* and allied *infrastructure* (as part of the home-delivery of grocery products), existing processes of one retailer and one logistics service provider were reflected. The close interconnection of existing and new processes (originated from e-grocery service models) has been extensively tested and applied in the course of real field trials.

The identified process steps were feasibility-tested in several trial phases (i.e. picking, packing and transport distribution). For this purpose, a large number of picking and packaging tests have been performed. Additionally a first field trial phase of testing the handling and distribution process (customer journey – from online order in web-shop to home-delivery receipt) with involved project members allowed a first documented and critically analyzed trial.

In terms of handling processes, a specific picking-procedure helped to develop in-store-picking for online orders: based on more than 100 orders picked (including process time recording) a statistical estimator for the picking time was derived. The process improvement (i.e. the reduction of the picking process time) is due to the intense learning curve effect, as shown in Figure 4.

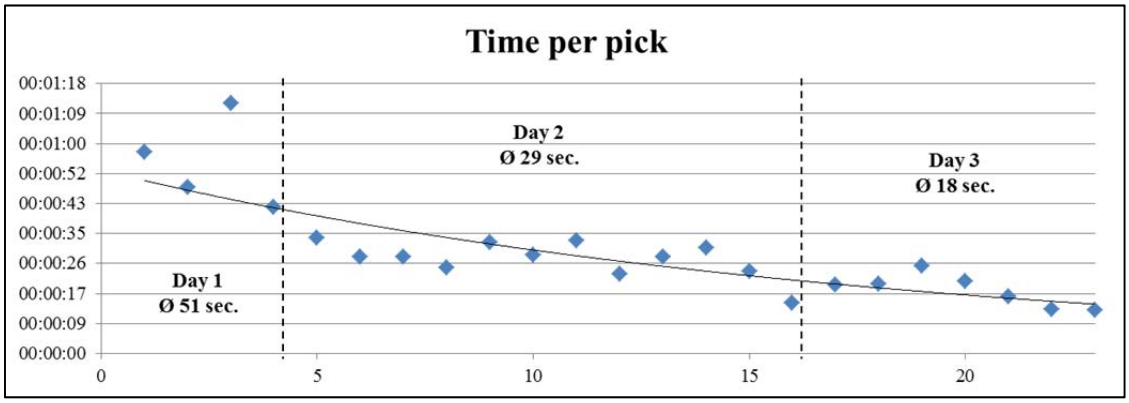

Figure 4 - Process improvement in picking time

Results on this store-picking test phase suggest that a time-frame of 1 minute for the *in-store movements* (from picking zone to shelves and back) and additional 7 *seconds picking time per item*.

Concerning packaging and identification of the appropriate transport container, reusable packaging options were evaluated through different tests. The selection criteria for the standard parcel comprised (i) insulation property, (ii) durability, (iii) suitability for machine handling and (iv) ecological requirements referring to cleaning and robustness. In addition, several temperature tests were performed: grocery products were packed together with diverse cooling elements. Long-term digital temperature measurement and spontaneous temperature tests enabled specific checking of freshness and product quality.

After the final packaging decision, a closing field trial (for the home-delivery option via a specific logistics service provider) was conducted to examine the *stability and functionality of established processes* – from the initial web-shop order to the final delivery point at the buyers' home. In this final field trial along the whole customer journey some remaining problem areas were identified and fixed. Before rollout, the *implications on logistical infrastructure and scalability for handling and distributing e-grocery goods* were set.

4.3. Implications on logistics' scalability

Based on relevant data and expected order volumes, the mentioned online distribution planning approach for an Austrian grocery retailer has been developed. The main purpose of this planning strategy in terms of logistics scalability was to find answers to the following questions:

- Assuming to have a specific amount of orders – in a multichannel-approach –, how many *stores are required for picking*, considering capacity constraints like working time and limitations in space (e.g. the figure aside)?
- What is the *best cut-off time for online consumer orders* to guarantee same day or next day delivery?

The developed concept and its aspects led to an applied "virtual retaility" concept (**virtual** = with a digital and multi-channel character; **retaility** = referring to the new reality in grocery retail business) and to a strategic cooperation between the involved retailer and a service provider in Austria.

To answer the first question, (i) **the available capacity per grocery store** (i.e. surface, maximum number of picking personnel able to work in parallel) and (ii) **the in-store capacity demand for order handling** (i.e. average picking time per order, number of orders per day – according to pre-calculations – and considering fluctuating demand) have been compared.

It has been determined, which number of orders would require a *store-picking process in two or more dedicated grocery stores*. Planned order volumes can be compared with actual orders in future (see Figure 5). In case of adequate increase in e-grocery orders the retailer thus has sufficient time to equip another grocery store for dedicated picking purposes.

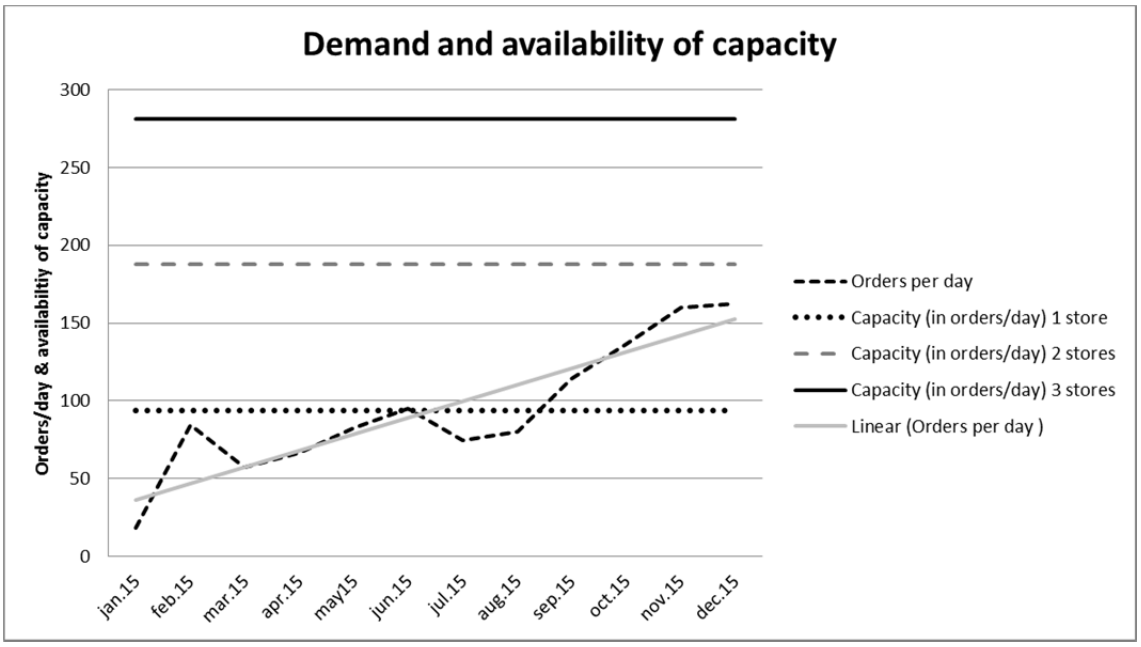

Figure 5 - Capacity demand & availability in e-grocery processing

To answer the second question, the most suitable **cut-off time for online grocery orders** has also be deducted on the basis of the required in-store picking time. Recognizing the *latest possible delivery time at local distribution location* (operated by the logistics service provider) ensures the successful home-delivery process ("same-day" or "next-day"). The estimated picking time has been determined already. In addition, loading and transport times were estimated. Using backward scheduling, the cut-off time was calculated to define the last possible moment for a consumers' order.

Elaborated results suggested **a mix of order picking and processing options** to be implemented in the retailers' e-grocery rollout. There are three options of processing within the logistics structure in the retailer's "virtual retaility" practice: (i) in-store picking, (ii) a combination of "fast-moving stock depot with in-store picking" (advantage of low shrinkage in low-moving product range) and (iii) a pure "dark-store" (dedicated retail warehouse – suitable for high volumes and shorter delivery times). Because of their given flexibility, these options are suitable for process handling increasing amounts in the online grocery segment.

Further the **distribution (i.e. delivery concept)** is currently performed in two different ways:

- *E-grocery reception points*: the delivery of goods ordered is completed by the retailer through own vehicles, where temperature-controlled depots are supplied with packed parcels, provided for self-pick-up.
- *Home delivery*: delivery of e-grocery orders is completed by the logistics service provider via established and standardized delivery network. In urban areas, a same-day-delivery service is available if ordered before 12 am. Goods are transported in appropriate insulated parcels that guarantee set quality standards up to 48 hours.

More and more Austrian grocery retailers start to enter multi-channel approaches. The underlying research is based on a practical task of a leading grocery retailer in Austria, entering the online grocery business with the implications of this research. Identified sales potentials and necessary aspects for distribution logistics processing influenced the retailer's strategic set of decisions.

5. CONCLUSION

The sharp e-commerce trends and the common mobile commerce activity of individuals change the retail sector significantly and have a big strategic impact on how retailers keep up with developments. Besides meeting consumer expectations and competing for market share, retailers in the Austrian grocery sector start to follow strategies in e-commerce and multi-channel business.

An Austrian grocery retailer launched the opening of an online channel, additionally operated to traditional grocery stores, in 2014. Online ordered groceries will be delivered nationwide (i.e. not only in cities but also in rural areas) and within a day delivery period, directly to the customer's home address. In addition to the home delivery service, a self-pick-up to collect the goods from temperature-controlled pick-up depots is available.

The shown hands-on planning approach – to determine the market and fulfilment potential – served as the basis for the applied logistical process structure in order to cope with potential order volumes of national online grocery sales. Under uncertain market setting, it enabled to identify sales potentials and to clarify logistics' scalability (referring to capacity utilization, locations planning, order handling, interface to service provider, etc.). In order to derive sales and resource figures, the method investigated (i) how respective online-grocery demand is expected to extend traditional (brick-and-mortar) sales and (ii) how established processing and distribution structures need to be adjusted to handle e-grocery order volumes. As solid indications in setting up distribution concepts for online grocery retailing lacked in Austria so far, this approach has been a distinctive new type of managing uncertainty in this specific e-commerce context. Because of no available regional experiences or past insights, the developed distribution-planning approach helped an Austrian grocery retailer to build up a supply chain strategy in e-commerce and to initiate cooperation with an established distribution service provider.

A central implication in course of the underlying research is the context-specific analysis for a regional grocery retailer in Austria, which limit the derived findings to a non-general validity. Future research is supposed to investigate a broader perspective of distribution models (e.g. in-store services or designed pick-up networks) of online ordered grocery products as well as further verifying regional sales potentials in online grocery retailing.

ACKNOWLEDGEMENTS

The team of researchers gratefully acknowledges the contributions of participating managers from the involved grocery retailer and logistics service provider.

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Integrating sustainable supply chain management and base of the pyramid research approaches: A literature review

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Abstract

Purpose

Base/Bottom-of-the-pyramid (BoP) projects addressing how companies contribute to fulfilling needs of the poorest population are currently seeing a move to more elaborate theory driven explanations. The links to (Sustainable) Supply Chain Management (SSCM) are frequently mentioned, but in a scattered manner. The aim of this paper is exploring relevant business issues within BoP literature by taking SSCM as one of the theoretical lens, thereby analysing which SSCM arguments are taken up in BoP related research.

Design/methodology/approach

The paper presents a structured literature review of BoP papers published until 2014 in peer-reviewed English-speaking journals available on web-of-science. The evaluation of BoP articles is carried out based on content analysis, where SSCM constructs are borrowed from Beske & Seuring (2014).

Findings

The findings of the paper highlight potential links between the two research streams i.e. BoP and SSCM. SSCM practices of long term relationship development, partner development, joint development, technological integration, enhanced communication, learning, stakeholder management and innovation have regularly been referred to and considered important by respective BoP scholars in context of BoP business environment.

Research limitations/implications

The paper offers insights into the links between the SCM & BOP research streams and sets ground for further theoretical exploration of the subject.

Originality/value

The paper applies SSCM theory to analyse BoP issues and thereby interlink the two research streams. This will be valuable for advancing both research streams, as SSCM offers related jobs sought and perceived by the respective BoP scholars as crucial in context of emerging economies.

Keywords: Base of the pyramid, Bottom of the pyramid, Sustainable supply chain management, Literature review, Content analysis.

1. INTRODUCTION

Growing concerns about the sketchy realization of philanthropic oriented endeavours towards successfully addressing the menace of poverty led Prahalad & Hammond (2002) to propose a market based solution to the challenge faced by humanity at large. The original consumer-oriented BoP perspective (Prahalad & Hammond, 2002), mainly arguing about addressing menace of poverty by appreciating BoP as the potential consumers of products and services of multinational corporations (MNCs), was sharply criticised by proponents of a more producer-oriented BoP perspective (e.g. Karnani, 2007). The producer-oriented BoP perspective argued about considering BoP as the potential producers and thus devising appropriate strategies to integrate poor in the value generating supply chain activities by developing their capabilities, instead of considering them as the potential consumers. The producer-oriented BoP rationale later on developed further into a more partner-oriented BoP approach, which advocates about considering the poor as efficient supply chain partners instead of treating them in silos of consumers or producers (London et al., 2010). Though the partner-oriented BoP perspective is gradually establishing its foot print, it is worthwhile highlighting that by and large, today the BoP scholars consider BoP 2.0 as more appropriate strategy of poverty eradication (Agnihotri, 2013; Arnold & Valentin, 2013; Chelekis & Mudambi, 2010; Reficco & Marquez, 2012). However, developed in response of a more consumer-oriented (BoP 1.0) BoP notion, it must be kept afore that BoP 2.0 (hereafter referred to as "BoP theory") has inherently taken some 'appropriate aspects', for example 'innovation' from BoP 1.0. The BoP markets present unique challenges quite different from business environments of the developed economies, such as non-existent or malfunctioning institutions to regulate free market mechanisms, poor communication infrastructure and challenge of satisfying the unique needs of low income consumers when compared to the needs of their counterparts in developed/formal markets having high purchasing power (Prahalad & Hammond, 2002, 2006; Rivera-Santos & Rufin, 2010; Rivera-Santos et al., 2012). Copying the traditional business logic in general and supply chain solutions in particular will not work in these emerging markets as they are drafted for serving the needs of formal markets (Schrader et al., 2012). Moreover as noted by Ansari et al. (2012, pp. 836) "BoP is still in a pre-paradigmatic state of development as an academic field". So there is a need to come up with innovative business strategies and ingenious supply chain solutions, adapted to the BoP business context to enable firms operate successfully in developing markets and play their part in alleviating the menace of poverty (London & Hart, 2004; Schuster & Holtbruegge, 2012).

Globalization has led firms compete on supply chain level (Chen & Paulraj, 2004). The ever growing body of business literature dealing with supply chain management (SCM) is one of the parameters highlighting the importance of supply chains in global business environment. Sustainable supply chain management (SSCM) though a relatively new but a more or less established management theory is gradually maturing (Seuring & Mueller, 2008). In their recent publication Beske & Seuring (2014) have proposed a theoretical framework highlighting the aspects differentiating 'sustainable' from 'conventional' supply chain. The paper is an effort to equip SSCM with a more coherent theoretical infrastructure. However, there are various research avenues yet to be explored by the management scholars in context of SSCM theory (Carter & Rogers, 2008; Chen & Paulraj, 2004). Similarly as has been noted by Halme et al. (2012, pp. 745) "Research on business solutions for poverty alleviation is still in its infancy, and therefore there is yet no coherent set of concepts". Little attention has been paid towards

using instruments in hand of SSCM theory for analysing the relevant issues in BoP research. Though one can conclude after having a glance at the literature published in the respective research streams that, both research streams aim achieving more or less similar goals, yet each is following its own path independent of the other. Serious effort has yet to be undertaken to establish sound theoretical links between the two management research streams. Such a theoretical link will not only be an effort towards equipping BoP with a coherent set of theoretical concepts but will also open new research frontiers for SSCM literature. In this regard, a conceptual SSCM framework will be used to analyse and explore the relevant issues in BoP, . Therefore, SSCM provides the theoretical lense for assessing the BoP discourse.

This particular paper has taken the SSCM constructs developed by Beske & Seuring (2014) to uncover the theoretical links between the SSCM and BoP research streams by analysing which of the SSCM arguments have been taken up by BoP scholars thus paving the way for comprehensive analysis and exploration of the BoP business issues using the tools provided by SSCM theory.

The paper is structured as follows: The first chapter comprises of a brief introduction followed by the chapter elaborating the basic terminology used in the paper. The following chapter details the research methodology employed to conduct the literature review. Results and discussion section will comprise the fourth chapter of the paper highlighting the findings of the literature review while including a brief discussion about the BoP relevant SSCM constructs. The very brief conclusion will be the last and concluding chapter of this article.

2. BASIC TERMINOLOGY

The term base of the pyramid (BoP) originally coined by Prahalad & Hammond (2002) is an acronym of the phrase “base/bottom of the pyramid”. The phrase itself refers to 4 billion people representing the bottom tier of the world income pyramid living on less than $9.05 per day. Moreover 2.6 billion people living in moderate and extreme poverty comprise a subset of BoP population living on $2.00 per day or less (Arnold & Valentin, 2012). Regardless of drawing precise income lines the argument stands firm that the BoP population is comprised of those who are “generally excluded from the current system of global capitalism” (Arnold & Williams, 2012, pp. 4). Though not being solely but mostly concentrated in the emerging economies of the world, people representing BoP are mostly participants of informal market economies of developing countries. These markets are characterized by weak institutional framework, poor infrastructural facilities, geographical dislocation, lack of financial services, and a vibrant participation of low income consumers with limited purchasing power (Hahn & Gold, 2014; Schuster & Holtbruegge, 2012). BoP theory advocates about business co-venturing with the participants of informal market economies, the poor. “The key claim of the BoP concept is that poverty can be alleviated through financially profitable activity” (Kolk et al., 2013, pp. 14) Though BoP theory considers local entrepreneurs mainly being small and medium enterprises (SMEs) of developing economies to be best suited to kick start the economic activity provided the challenges obstructing the economic activity are addressed (Karnani, 2007), it also recommends MNCs to engage in the business activities in predominantly unexplored informal market of billions of potential consumers by working in partnership for the co-creation of mutual value. This value creation is at the heart of operations and supply chain management and links into the social dimension of sustainability. Hence, there is an almost obvious link to this body of literature asking for further research (Gold et al. 2013).

According to Seuring & Müller (2008, pp. 1700) SSCM is defined as “the management of material, information and capital flows as well as cooperation among companies along the

supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environment and social, into account which are derived from customer and stakeholder requirements". In line with principles of cooperation and coordination advocated by BoP theory (Schuster et al., 2014; Rivera-Santos & Rufin, 2010; Schrader et al., 2012), according to this definition SSCM not only considers cooperation among all the respective players as corner stone of a sustainable supply chain but also defines the ultimate objective of this collaboration to be the realization of goals of sustainable development. Implicit in the definition is consideration of the aspirations of community at large while devising supply chain strategy and delineating respective objectives.

Based upon the particular definition Beske & Seuring (2014) have developed specific constructs to discriminate sustainable supply chain from a conventional supply chain. The respective constructs or 'categories' & individual 'practices' (terms used by the developing authors) cover strategic, structural as well as operational aspects of supply chain. It seems appropriate to introduce the terms 'category' and 'practice' as they have been taken up by Beske & Seuring (2014). The term category is used by the respective authors "as an umbrella term to group and sort the different practices and link them to relevant issues of SSCM and SCM respectively" (Beske & Seuring, 2014, pp. 323). Whereas a practice is: "the customary, habitual or expected procedure or way of doing something" (Beske & Seuring, 2014, pp. 323). A very brief description of the categories and practices has been presented in (Table 2.1) the table presents the reader with a brief description of the SSCM categories and practices which will be frequently and repeatedly referred to in the later sections of the paper.

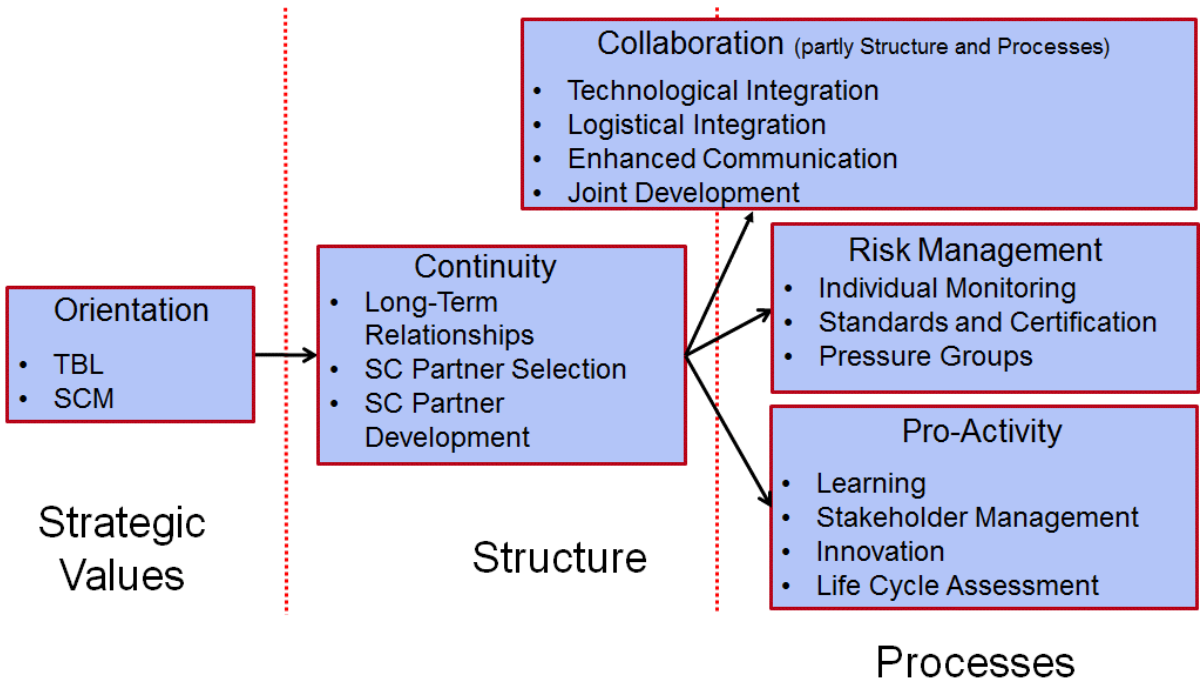

Figure 2.1: SSCM categories and practices (Beske & Seuring, 2014)

Since the SSCM framework comprehensively covers the various hierarchical facets of sustainable supply chains, starting from the strategic orientation level through the structural and design aspects to the process and operational part of a respective sustainable supply chain, the framework can strongly serve the purpose of this paper. The single constructs are briefly explained in Table 2.1.

It is admitted that taking just this one framework has its limits. Yet, the paper serves as a first step towards the quest of investigating BoP business issues through theoretical lens of SSCM.

*Table 2.1: Overview of SSCM categories and related practices (*Own illustration based on Beske & Seuring, 2014)

Categories	Practices	Description
Orientation	**1**. Dedication to triple bottom line (TBL) **2**. Dedication to supply chain management (SCM)	Concerned with the strategic values level of a supply chain, **orientation** calls for top-management support for integrating principles of **TBL** and a dedication towards **SCM** in the organizations strategy for reaching the competitive advantage.
Continuity	**3**. SC partner development (PD) **4**.Long-term relationships (LTR) **5**. SC partner selection (SEL)	Speaking about the structure of a particular supply chain **continuity** in line with the aspects of SSCM asks for developing **long term relations** with reduced number of selected **supply chain partners.** The practice intends to **develop** weak supply chain partners for increasing overall supply chain performance.
Collaboration	**6**. Enhanced Communication (EC) **7**. Technological integration (TI) **8**. Logistical integration (LI) **9**. Joint development (JD)	Situated at both structural and operational levels of a supply chain the category encompasses issues encouraging **collaboration** e.g. IT infrastructure for **enhancing communication**. Being one-step further than cooperation and long term oriented this category summarises and deals with the actual practices concerned with the sustainability. For example practices like **technological** and **logistical integration** and formation of cross functional teams leading towards **joint development**.
Risk Management	**10**. Standards and certification (CER) **11**. Selective monitoring (IM) **12**. Pressure groups (PRG)	In order to counter the risks associated with the adoption of sustainable practices in a supply chain the **risk management** category asks for adoption of **standards and certifications** not only to **monitor** suppliers but also to answer the critiques of **pressure groups**. The category based at operational level is imperative to averse the risks associated with higher dependability on reduced number of suppliers.
Pro-activity	**13**. Learning (LEA) **14**. Stakeholder management (STM) **15**. Innovation (INN)	Companies engaged in the sustainability are considered **pro-active** since they devise strategies at operational level to **learn** about the market requirements by actively engaging all the respective **stakeholders** in

	16. Life-cycle assessment (LCA)	business operations to formulate **innovative** products. These innovative products are proactively envisioned with possibility of recycling and reuse and thus include a **life-cycle assessment**.

3. RESEARCH METHODOLOGY

Structured literature reviews are an important tool for managing the diverse knowledge base for an academic inquiry and to develop the existing body of literature further. As highlighted by Gray (2014, pp. 98) "the literature review demonstrates the essential theories, arguments and controversies in the field and highlights the ways in which research in the area has been undertaken by others".

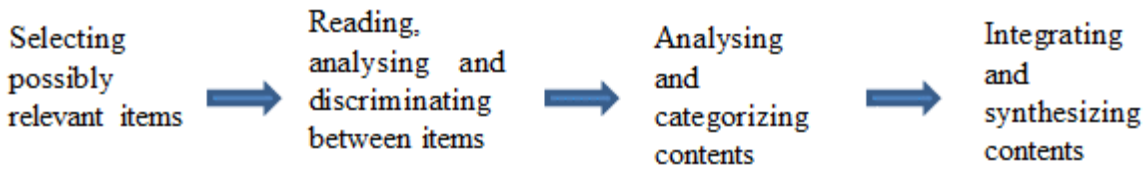

Figure 3.1: Literature review process (Hart, 2001, 2014)

The literature review can be defined as "… a systematic, explicit, and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents (Fink, 2014, pp. 3)". Following the literature review process proposed by Hart (2001) his particular study was carried out in four steps shown in (Fig. 3.1)
It is crucial for a literature review to define clear boundaries to delimitate the research (Seuring & Gold, 2012). Defining boundaries of the research not only helps the researcher staying focused on the objectives, but also helps in the navigation while searching for relevant literature. The following boundary lines have been drawn and taken care of during the course of this literature review.

1. Research articles in scientific journals using English as the prime language of publication were selected for review.
2. Being a comprehensive and easy to use research database "web of science" was used as the prime source for searching and collecting respective articles.
3. Article search was carried out using two key words i.e. 'base of the pyramid' and 'bottom of the pyramid.
4. The search for the articles was made in the research domains of "business and economics", "social sciences & other topics" & "operations research and management sciences".
5. Only the published articles considering any of the SSCM categories and practices identified by Beske & Seuring (2014) relevant for BoP were included in the literature review.

The first two steps of the literature review process will be briefly highlighted in this section, while the latter two will be dealt with more detail in results and discussion section of this paper. Since following a structured approach while collecting the material for literature review is an imminent requirement of a systematic literature review the following sub-sections will elaborate the scheme of action followed while searching and collecting relevant articles.

3.1. Selecting possibly relevant publications

Selection of appropriate literature to be reviewed depends heavily on the aim of the particular literature review. In context of the specific aims of this study the inclusion of the literature dealing with both SSCM and BoP issues at the same time was the only viable option.

Following the literature review process (Figure 3.1) a systematic procedure was followed while searching and collecting the respective articles. The initial search in three research domains (business and economics, social sciences & other topics, operations research and management sciences), using two different (however related) key words (base of the pyramid & bottom of the pyramid) produced about 212 research articles. After excluding the duplicates (same articles appearing while using different key words) and the papers dealing with subjects like medicine the authors of this paper were left with 136 papers to thoroughly screen further. After the first phase dealing with the search for possibly relevant papers was complete, papers were screened further to select the most appropriate ones (i.e. the BoP papers explicitly dealing with the SSCM constructs developed by Beske & Seuring (2014)) for proceeding further with the literature review.

3.2. Reading, analysing and discriminating

Instead of going for a specific key word search within the individual articles for sorting out 'the inappropriate ones', contents of all the remaining articles have been thoroughly examined. The practice proved to be useful in identifying the most relevant papers to be included in this literature review. Finally only those BoP papers have been selected and included in the review process, which were explicitly dealing with any one or more of the SSCM categories and practices developed by Beske & Seuring (2014). The research articles dealing with issues like factors effecting purchasing decision of BoP customers, impact of institutions on BoP consumers etc. have been excluded. The final number of articles included in this literature review thus has come to be 76 (Fig. 3.2).

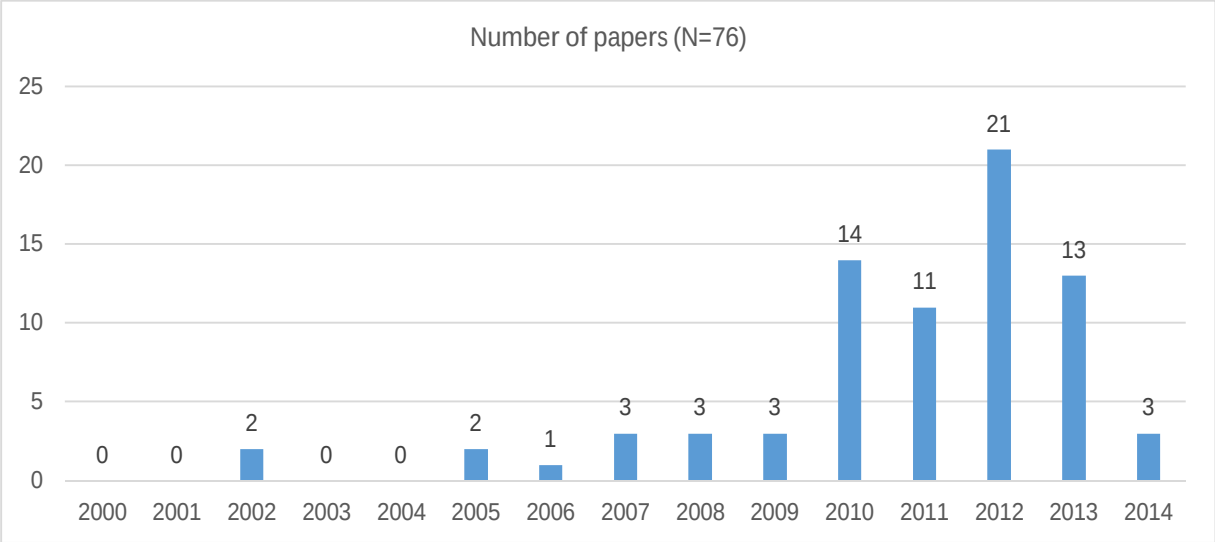

Figure 3.2: Distribution of the publications per year

While screening individual articles, descriptive data of the articles included in the review was also recorded. A careful analysis of the data thus gathered produced interesting results. Descriptive analysis suggested that a clear majority i.e. 32% of total publications included, were

published in Indian context. As far as the methodology employed by the BoP researchers is concerned, 35% of papers were conceptual and about 56% of the remaining papers were either case based conceptual papers or simple case studies. This is in line with the findings of Kolk et al (2013) who also pointed out that the bulk of the BoP papers were either conceptual papers or conceptual papers with examples (mostly cases) or simple case based studies. This myriad of conceptual papers also is a clear indication of the fact that BoP research approach is in its evolution phase. As far as the data collection technique employed by the scholars is concerned 75 % of the total papers included in the review were case based (either single or multiple case studies).

Parallel with the findings of Kolk et al. (2013) the findings of this paper also reveal that "India accounts for the vast majority of illustrations found in BoP articles" (Kolk et al. 2013, pp 11). However with the appearance of more studies focusing on other developing countries particularly Africa and Latin America we will be able to get a more holistic picture of BoP phenomenon. Coming down to the supply chain focus of the BoP scholarship, a homogenous distribution of papers can be easily recognized, with 30%, 30% and 33% of the papers included in the literature review taking a focal, dyad and supply chain wide perspective respectively.

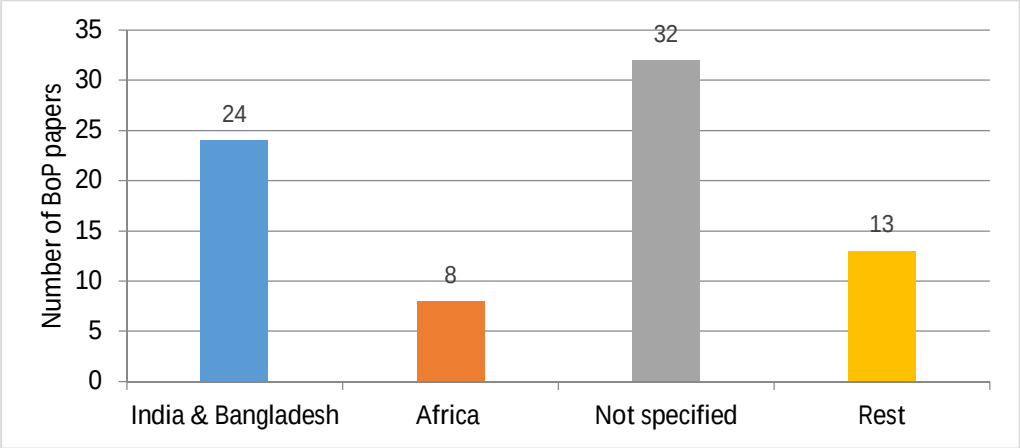

Figure 3.3: Region based distribution of BoP papers

4. RESULTS

4.1. Analysing and categorising contents

The model devised by Hart (2001) proposed that one should start thorough analysis and categorization of publications to be included in the review after completing the second step i.e. after the phase of selection of all the relevant material has been completed. For the selection of appropriate publications the model suggests that individual papers should be screened for selecting the most relevant papers. In this particular study for the sake of time benefit the process of categorization of the contents of the relevant publications started while selecting the relevant papers. Since the research boundaries have already been defined and SSCM categories and practices been selected, the relevant BoP papers were categorized accordingly while screening individual papers during the selection process. Not only were the publications coded against the SSCM categories and practices mentioned in Table 2.1, but also the relevant descriptive data was collected during the course of the study. Descriptive data elaborating the research methodology, method of data collection, regional focus, supply chain focus and

respective role the specific BoP actor is playing in the respective supply chain was collected to get a deeper understanding of the issues that remained focus of the BoP scholars.

It was highlighted by the subsequent analysis of descriptive data that 54% of the papers were considering "BoP consumers" as their core object of study. Poor serving other roles in a supply chain like suppliers, manufacturers and distributors received very little attention of scholars i.e. 5%, 15% and 3% respectively. About 30% of the publications did not mention explicitly about the role of BoP in particular supply chain they are concentrating on. The industrial focus in the BoP literature shown in (Figure 4.2) depicts an almost analogous dissemination of papers across different industrial sectors in the BoP market environment. However in the case of papers not specifying peculiarly the industrial focus of authors it has been observed that the respective papers were mostly trying to conceptualize about general BoP market issues and dynamics (Ansari et al., 2012; Arnold & Valentin, 2013). Summing up the debate, the general focus of BoP scholars by far has been the consumers operating in the BoP markets without confining them to a particular industrial or economic sector.

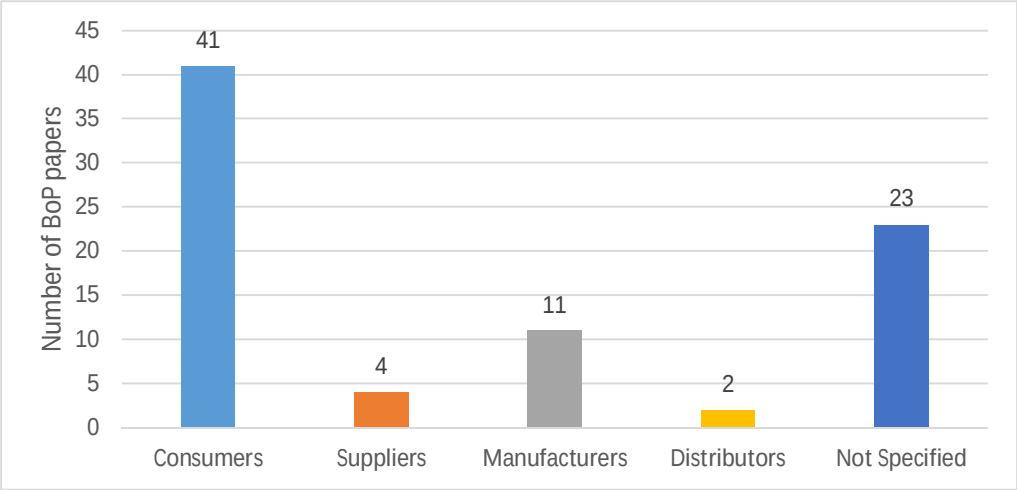

Figure 4.1: BoP actors focused by BoP papers

4.2. Integrating constructs and synthesizing results

After coding the BoP publications against the established SSCM categories and practices the next and most crucial part of the review process was the subsequent analysis of the data for compiling results. The objective of theoretically bridging the BoP and SSCM was meant to be achieved by identifying the respective SSCM constructs which the BoP scholars considered crucial for BoP market environment and had most frequently referred to.

After the coding process was complete it was easy to identify the SSCM constructs considered imperative in a BoP market context. It seems appropriate to highlight again the fact that only the publications mentioning a positive note about respective SSCM categories and practices developed by Beske & Seuring (2014) were coded against the particular SSCM constructs. Though it was a very rare case, the papers considering the particular SSCM categories and practices not relevant for BoP business environment were simply not coded against the particular categories and practices.

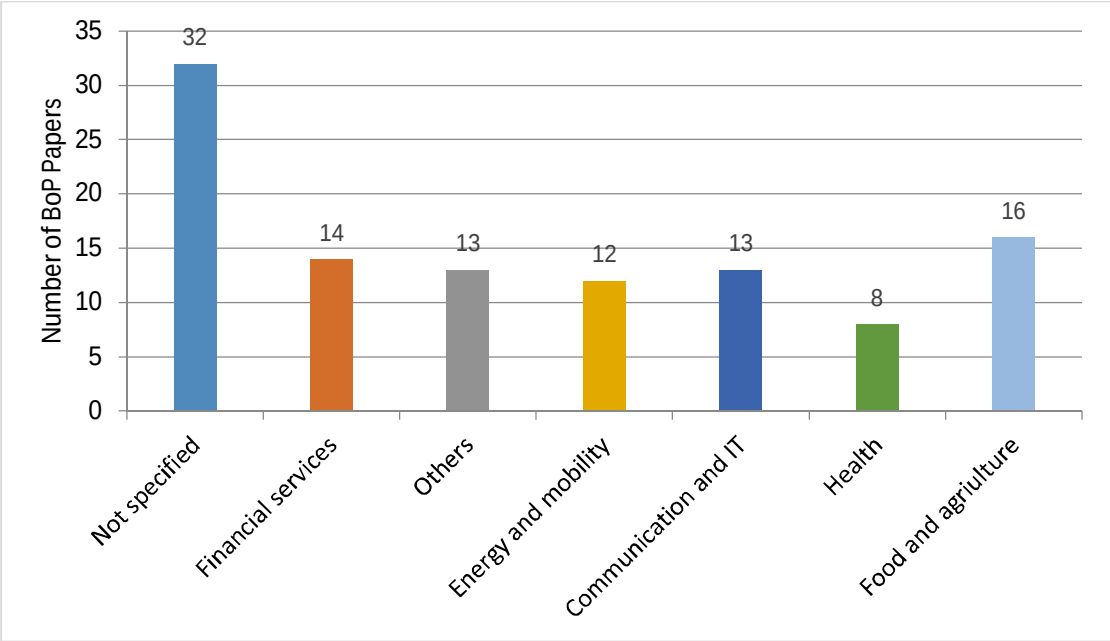

Figure 4.2: Industrial focus of BoP papers

By calculating the number of the papers mentioning each of the SSCM practice, it became clear that there are certain SSCM aspects considered by BoP scholars relevant for the supply chains operating in the informal market economies (Fig 4.3). The results further revealed that only the categories of continuity, collaboration and pro-activity are considered important by the scholars in BoP markets. Moreover, not all the SSCM practices in the particular category are considered important for BoP market.

The results revealed that the supply chain practices long term relationship & partner development are considered decisive in category continuity; joint development, technological integration and enhanced communication in category collaboration and the supply chain practices learning, stakeholder and innovation in category pro-activity. A brief commentary on each of the categories and the corresponding practices are presented below.

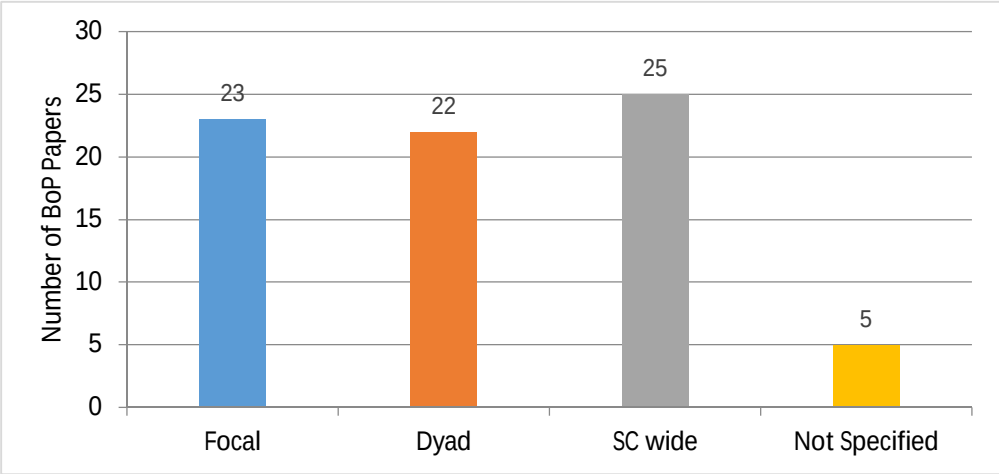

Figure 4.3: Supply chain focus of publications

4.2.1. Orientation

The first category in the SSCM frame work proposed by Beske & Seuring (2014) calls for the full support and active involvement of top management in initiatives dealing with integrating principles of triple bottom line (TBL) and supply chain management (SCM) in the organizational strategy (Table 2.1). However as depicted in (Fig. 7), the results of the literature review suggest that the BoP scholars have commented and argued about this category and the respective practices in context of BoP supply chains only rarely. This suggests that the BoP scholars are sceptical about the respective category and the practices to have a decisive role while formulating strategies for the supply chains in the BoP context.

Among the possible reasons for ignoring the category and the corresponding characteristics from becoming an integral part of strategic principles shaping the decisions concerning a BoP supply chain are enlisted under:

1. Certain issues (e.g. economic and social issues) matter more and need immediate attention (Halme et al., 2012, Calton et al., 2013) than others (e.g. environmental issues) in deprived societies.
2. BoP scholars are focusing more on the integration of the poor in the formal economy (Akula, 2008, Berger & Nakata, 2013) than the issues concerning the affluent supply chain actors and so have avoided taking a full supply chain perspective in their publications.
3. The published literature on BoP is mostly build on case studies dealing with business-to-consumer (B2C) issues (Hudnut & DeTienne, 2010) thus not taking a thorough supply chain perspective of which business-to-business (B2B) issues are an integral part.
4. Primarily BoP literature demands MNCs to engage in the BoP market activities for the fulfilment of entrepreneurial ambitions like market expansion and profit earning and not for achieving the novel motives advocated in the sustainability theory (Karnani, 2007; Prahalad & Hammond, 2002).

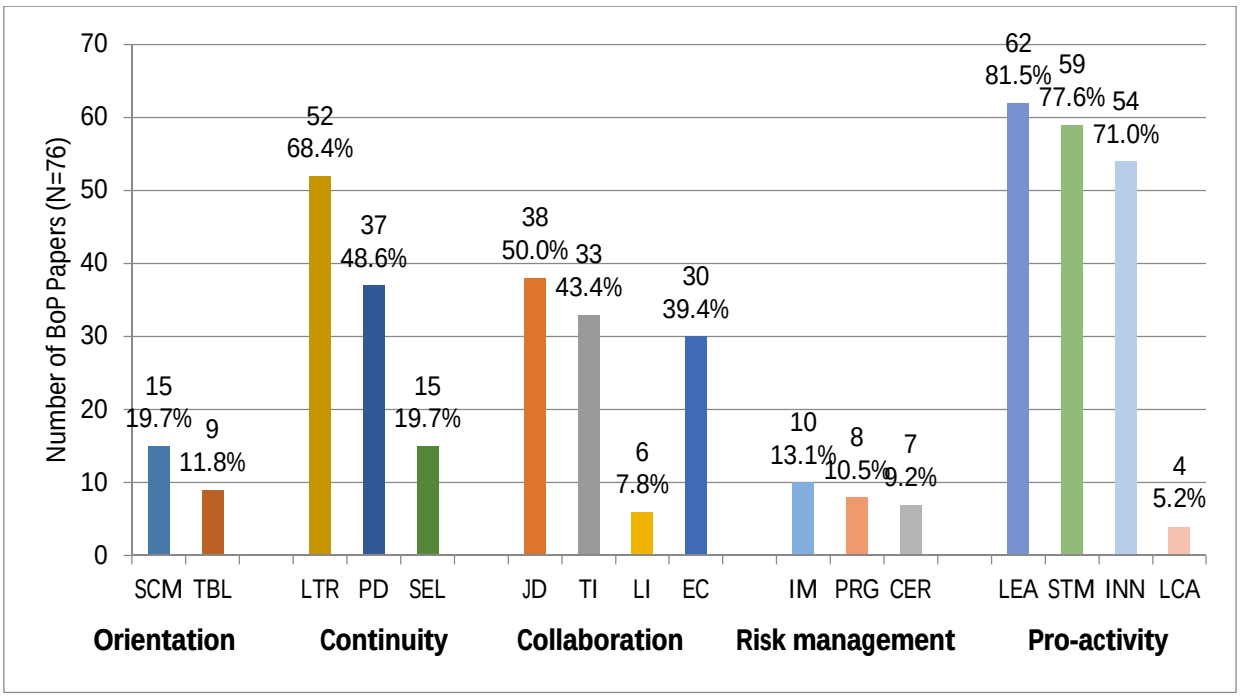

Figure 4.4: Number of papers referring to each of SSCM practices

4.2.2. Continuity

The second category proposed by Beske & Seuring (2014) is concerned with the structure of a particular supply chain. The respective practices are concerned with building long-term relations with supply chain partners and subsequent selection and capability development of weak supply chain partners with objective of increasing the overall performance of supply chain (see Table 2.1). The results of the literature review illustrate that the BoP scholars are advocating about the development of trustworthy long-term relations between MNCs and BoP (Gold et al., 2013, Hall et al., 2013, Karnani, 2007) for the development of the later while focusing less on the practice of partner selection. Though the logic behind neglecting the practice of partner selection was hard to figure out, however it is expected that any future empirical investigation might bring afore interesting insights concerning this over sightedness.

4.2.3. Collaboration

The third SSCM category collaboration includes practices dealing with both structural and operational aspects of a sustainable supply chain. The results of this particular literature review suggest that BoP scholars consider the practices of the enhanced communication, technological integration and joint development imperative for functioning of an efficient supply chain in the BoP context (Kistruck et al., 2013, Vachani & Smith, 2008). The practice of logistical integration among the collaborating supply chain partners has not been considered critical by the BoP scholars. The plausible reasons for the fact could either be:

1. The BoP scholars are dealing with logistical integration under the banner of technological integration or capability development.
2. The BoP researchers consider the practices like enhanced communication, relationship building and technological integration more vital for the development of BoP, which could then compensate for the logistics related limitations faced by the BoP and MNCs alike. It has been proposed for example that MNCs can satisfy their accessibility limitations to reach geographically diversified consumer base by building capabilities of the BoP to enable them to act as local distributors of MNCs (Chelekis & Mudambi, 2010).

4.2.4. Risk management

The risk management though being of central importance in any business activity has gathered little attention in BoP publications (Figure 4.4). While commenting on the critical nature of risk in present day business Khan et al. (2008, pp. 412) mention “risk is an ever-present aspect of organisational life, whether the risk concerns investment decisions, recruiting and developing people, the launch of new products and services, or the management of supply chains”. Efficient risk management strategies being at the core of business success in present day high competitive markets cannot be ignored. Moreover, importance of this practice increases manifold in informal market settings characterized by aspects like political instability, malfunctioning institutions, poor infrastructural facilities and so on (Rivera-Santos & Ruffin, 2010; Arnold & Williams, 2012; Hart, 2005; Ramachandran et al., 2012). In such a scenario the possible proposition (as no empirical data is available in support or opposition of the claims) explaining the poor appearance of the category in this literature review could be:

1. The BoP scholars do not consider the respective risk management practices included in this category as relevant for the BoP business environment.

Having said that, we need to point towards the dearth of BoP literature dealing with issue of risk management. Scholars have yet to focus more on the risk management aspects of BoP and come up with specific constructs to help practitioners design their risk management strategies.

4.2.5. Pro-activity

The last SSCM category pro-activity includes three practices relevant for supply chain needs operative in informal markets of developing economies. The results of the review show that

proposals concerning building relationships with different stakeholders in developing economies to learn about the prevailing ground realities about market dynamics have regularly been put forward by BoP scholars. Along with that the need of formulating innovative business solutions and coming up with innovative products for successfully addressing the BoP challenges has remained one of the core focus of respective scholars (Shivarajan & Srinivasan, 2013, Vachani & Smith, 2008, Weidner et al., 2010). However, LCA normally associated with post-manufacturing/factory life of products has gathered little attention in BoP literature. One among the possible reasons being that the LCA is a too modern and advanced concept to be considered relevant for such a young and evolving market as BoP.

5. Discussion and future research directions

The contribution this paper makes is a first set of SSCM practices being put into the context of the BoP literature. By presenting a set of SSCM practices relevant for BoP (Reficco & Marquez, 2012, Calton et al., 2013, Hart, 2005) the paper augments towards bridging the two research streams together on foundations of sound methodological exploration of literature (Spens & Kovacs, 2006). This assessment contributes towards knowledge generation and allows identifying future research needs. Returning to Figure 4.4, it became apparent from the findings that certain SSCM practices are overlooked so far. This holds e.g. for risk management which seems highly relevant in the context of emerging economies, but gathered little attention of the concerned BoP scholars. The literature review thus further highlights the fact that though being emphasised by scholars like (Karnani, 2007) the rationale of BoP has yet to mature further on certain aspects of pro-activity. Staying at the interpretation of the findings, also other supply chain issues, particularly supplier selection and logistical integration received little attention. Contrastingly, long term relationship, collaboration issue, and stakeholder integration are frequently mentioned, confirming the critique of Karnani (2007). This would be an opportunity for SCM-researchers addressing this gap in research. The findings of the paper also highlight the fact that management researchers and practitioners have yet to come up with more vigorous and context relevant SSCM practices to fulfil the needs of informal market economies (Ansari et al. 2012).

The results of this literature review indicate that there are certain SSCM constructs which are considered by the BoP scholars as relevant for satisfying the specific needs of BoP. Based upon the findings of this literature review it is proposed that there are positive potential avenues for integrating SSCM and BoP research streams (Murphy et al., 2012, Sanchez & Ricart, 2010). However, interesting insights were also revealed in the sense that some hard core SCM constructs like logistics integration (Chen & Paulraj, 2004) gathered little attention of the BoP scholars. Concerned scholars may pursue more vigorous research efforts by employing more SSCM and SCM constructs developed by other management scholars for consolidating the two research streams (Seuring & Müller, 2008, Chen & Paulraj, 2004). Moreover empirical validation of the findings of this paper and of any future effort undertaken to explore the commonalities between SSCM and BoP could help to build strong theoretical foundation for further development of rationale. Another area of interest for future researchers could potentially be to explore if there are any contingencies among the various SSCM constructs, based upon the findings of this and/or any future literature reviews conducted on similar lines. It would be quite interesting to see ‘what leads to what’ in the context of the BoP and then validating those findings empirically.

6. CONCLUSION

BoP and SSCM research approaches either directly (BoP) or indirectly (SSCM) propose potential solutions to address one of the most pressing issues faced by humanity at large 'the poverty'. Both of the research streams advocate about issues like business partner development, stakeholder involvement, innovation, technological integration, enhanced communication, long term relationship development with other supply chain actors and learning however irrespective of each other and while remaining within the confinements of their own boundaries. By far, to the best of our knowledge, no prominent effort has been undertaken to explore how both of these research streams are interlinked to present collective solutions to the challenge. By conducting a comprehensive systematic literature review we have tried to set the direction towards filling this research void. We are certainly aware of the limitations of our research findings however the effort will help draw the attention of BoP and SSCM scholars alike towards this underexplored research avenue. Moreover by presenting a blueprint conjoining the SSCM and BoP we are confident that the paper will help the concerned scholarship streamline their research and focus more on the respective issues highlighted in this article.

As far as the question of research quality is concerned, the construct validity in the paper is ensured by using the SSCM constructs already established in the SSCM literature. However, with coding process not being scrutinized by multiple researchers we accept and acknowledge the limitation of this paper in terms of reliability.

7. REFERENCES

The full list of 76 papers would be available upon request. It would take too much space listing all of them. The papers contained in the sample analyzed are marked with an *.

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A SIMULATION MODEL FOR THE ASSESSMENT OF THE NORTHERN SEA ROUTE TROUGHPUT

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ABSTRACT

Purpose
The purpose of the research is to analyse factors affecting the transit of vessels via the Northern Sea Route and to develop a simulation tool modelling the transit process accounting for ice conditions, icebreaker support requirements and convoy formation.

Design/methodology/approach
Discrete-event simulation is used to model the transit process.

Findings
The developed model allows for the assessment of the route throughput measured as the fraction of transit orders satisfied during the navigation period, and the average order delay time, affected by the total number of transit orders and the number of available icebreakers.

Research limitations/implications
The information on order processing, the procedure of convoy formation and customers' logic behind order cancellation for the transit via the route is limited and needs further investigation.

Practical implications
The developed approach is valuable to shippers and transport providers as a means for evaluation of the expected average delay time from the requested transit order start date.

Original/value
The value of the research is in the development of a novel approach for modelling of the vessels' transit via the Northern Sea Route.

Keywords: arctic shipping, icebreaker support, sea route throughput, simulation modelling, transit order processing

1. INTRODUCTION

The interest for the transportation via the Northern Sea Route (NSR) increased significantly in the last decade. It can be primarily explained by the effects of global warming that affected the Arctic and thereby new economic possibilities have appeared. Marine routes between Europe and China are approximately 40% shorter compared to the ones via the Suez Canal. This makes the transit through the NSR more attractive in terms of time and cost savings (Østreng et. al., 2013). Originally, the NSR was used by the USSR only for internal purposes and for just several months a year due to severe weather and navigation conditions. Ice reduction and consequently the extension of the navigation period changed the situation drastically. Countries with territories in the arctic region began to see new possibilities for extracting the mineral and especially petroleum resources available on the shelf. According to the US Geological Survey conducted in 2008, the Arctic region contains around 22% of the world's undiscovered oil and gas resources (Bird et al., 2008). In recent years Russia has announced heavy investments into port and communication infrastructure along the NSR and search and rescue and emergency preparedness resources. Modernization of the existing icebreaker fleet began with orders for new vessels. Russia has an ambitious plan to provide a year-round navigation with the aim of expanding the commercial use of the NSR. Many companies involved in trade between Europe and Asia express interest in transportations possibilities via the NSR motivated by potential timesaving. In 2009, the first commercial voyages of two vessels, Beluga Fraternity and Beluga Foresight, occurred via the NSR (Associated Press, 2009). In 2013, in total 71 vessels navigated in the NSR waters which is 65% more than in the previous year (Northern Sea Route Information Office, 2015a).

Despite the fact that the ice cap in the Arctic has been reducing and the period of navigation was extended, a vessel navigating the NSR waters must comply with the icebreaker support requirements in accordance with Rules of navigation in the water area of the Northern Sea Route, approved by the Ministry of Transport of Russia, January 17, 2013, hereafter Rules, which are not in itself a part of Russian legislation (Rules of navigation in the water area of the NSR, 2013). Icebreaker support can only be performed by icebreakers authorized to navigate under the state flag of the Russian Federation (Northern Sea Route Information Office, 2015b). Icebreaker support guarantees safe navigation in the NSR waters and is dependent on the vessel's ice class. A vessel can be supported by one or more icebreakers either individually or as a member of a group of vessels called a convoy or a caravan (Šarlaj, 2015). Depending on ice conditions the size of the convoy will vary between two to four vessels. The number of icebreakers in operation is limited. In case of a large number of orders for the same time period the existing icebreaker fleet may not be able to satisfy all orders within the planned timeframe. This will result in a queue of orders for transit, and, consequently, some customers may decide to cancel their order. Customers may experience delays from the planned convoy departure date due to mainly two reasons: waiting for the icebreaker or waiting for the other vessel(s) assigned to the same convoy (Mikhaylichenko, 2014).

There have been several studies dedicated to transit shipping in the Arctic. Mulherin et al. (1996, 1999) presented a Monte Carlo-based transit model developed for the analysis of costs and transit times of transportation via the NSR. A case study applying computer simulation was conducted by Somanathan et al. (2009). The authors investigated economic viability of the North West Passage versus Panama Canal for shipping between Northeast America and Japan. Liu and Kronbak (2010) conducted a case study analysing the economic potential of the NSR as an alternative to the Suez Canal. The study focuses only the on economic aspects of the NSR and ignores navigation issues. Schøyen and Bråthen (2011) considered a case

from bulk shipping comparing the Northern Sea Route and the Suez Canal transportation alternatives. The authors assessed the potential benefits through cost reductions of navigating via the NSR and the disadvantages connected to uncertainty and risks compared to transit shipping via the Suez Canal. Bergstrøm et al. (2015) presented a simulation-based approach for assessing an arctic maritime transport system that is robust against uncertain future ice conditions. A case study is carried out to investigate the performance of the transport system for various future ice scenarios. Choi et al. (2015) presented an ice navigation system for ships operating in the Arctic region that handles uncertainties caused by sea ice. In the developed system, the ice model simulates dynamic sea ice behaviour and delivers obtained results as an input into dynamic stochastic path planning optimization model. The literature dedicated to the transportation via the NSR basically covers the problems of its economic efficiency. Some papers focus only on costs associated with transportation, but some in addition take into account navigation issues and ice conditions for assessing transit times using simulation modelling. There is one study dedicated to the routing problem that handles uncertainty caused by the sea ice (see Choi et al., 2015). As far as we know, there are no studies dedicated to the analysis of the NSR transit capability for an increased flow of transit orders under the limited number of icebreakers in operation.

The aim of the research is to model the NSR transit system as a queue of caravans waiting for the required icebreaker support and to analyse the throughput capability of the NSR with respect to the number of available icebreakers taking into account ice conditions.

For the purpose of our research we define two main characteristics of the NSR transit. First, the average delay time from the requested transit order start date and, second, the fraction of transit orders satisfied during the navigation period. These characteristics are dependent on the following factors: ice conditions along the route, total number of orders for transit, number of available icebreakers, procedures for exercising icebreaker support requirements and customer behaviour in case of delays. Information concerning the estimation of the average delay from the requested transit start would be valuable for companies interested in transport services involving the NSR.

The transit via the NSR can be represented as a stochastic process influenced by uncertain ice conditions and a random pattern of customers' orders arrival. In addition, customers' decisions are influenced by their preferences which are prone to changes over time. Discrete-event simulation modelling is used for analysis in this research since it allows for modelling transits via the NSR as a discrete sequence of events in time, including randomness through defined probability distributions, and can be used to describe the transport system's logic and structure.

The rest of the paper is organized as follows. Section 2 provides general information on NSR navigation together with an overview of icebreaker support requirements and some details on prevailing ice conditions. In Section 3 we define the research objective along with the necessary assumptions and simplifications. In Section 4 the simulation model is discussed in detail. The experiment setup and obtained results are presented in Section 5. Section 6 provides some concluding remarks and suggestions for future research.

2. NAVIGATION ALONG THE NORTHERN SEA ROUTE

In this section, we provide general information on the navigation routes in the waters of the NSR, rules of navigation including icebreaker support requirements, and a short description of prevailing ice conditions in different navigation periods.

2.1. General information on the Northern Sea Route

The NSR is an Arctic marine route that goes along the northern coast of Russia from Novaya Zemlya, either from Kara Gate or from Dezhnev Cape, to the Bering Strait. It extends for around 3000 nautical miles along the coastline and passes through four Arctic seas: the Kara Sea, the Laptev Sea, the East Siberian Sea and the Chukchi Sea (Northern Sea Route Information Office, 2015c).

The NSR is a segment of the so-called Northeast Passage (NEP) stretching from Northern Europe to the Far East, which provides a shorter passage by sea to Asia compared to routes that go via the Suez Canal. Quite often notions of the NSR and the NEP are used interchangeably (Buixade et. al. 2014). The total saving in transit distance from Europe to Asia, depending on ports of origin and destination, is 35-60% compared to transit via the Suez Canal (Østreng, 2013).

The NSR is not defined by only a single passageway, and there are a number of possible routes shown in Figure 2.1 by lines starting at the western and the eastern corner points of Novaya Zemlya island and ending at the cape point of the Bering strait. The actual route is determined for each transit case and vessel, and depends mainly on current ice conditions and vessel's ice class.

The navigation in the NSR waters has historically mainly occurred during summer and autumn, with the highest number of passages taking place in the five-month period between mid-June and mid-November. This is when the ice coverage is lowest and waters of the Barents Sea are free of ice. The western part of the NSR from Murmansk across the Kara Sea to Dudinka and Norilsk can be used for year-round navigation (Arctic Marine Shipping Assesment Report, 2009).

2.2. Icebreaker support requirements

Currently the government body that is responsible for organizing navigation in the water area of the NSR is the Northern Sea Route Administration (NSRA)[1]. It was officially established on March 15, 2013. Some of the main functions of the NSRA are as following: receiving and considering applications for navigation, issuing permissions for navigation, making recommendations on route development and utilization of icebreaker fleet, rendering information services related to the NSR water, and assistance in the organisation of search and rescue operations (The Northern Sear Route Administration, 2015a).

The NSRA authority mainly regards coordination and administration of navigation. It is not authorised to manage the icebreaker fleet and make decisions regarding icebreaker support. These functions are spread between several state and commercial enterprises out of which the main actor is the state-owned Atomflot with the fleet of seven nuclear icebreakers of different power capacities three out of which were not in operation as of December 2013 (Rosatom, 2013). For a complete list of the icebreaker enterprises we refer the reader to the webpages of the NSR Information Office (Northern Sea Route Information Office, 2015b).

Place and time of the beginning and the end of navigation under icebreaker support is to be agreed upon by the ship owner and the company providing icebreaker support, hereafter icebreaker provider. As mentioned earlier, the vessel can be escorted by an icebreaker either alone or as part of a convoy. Furthermore, in some cases more than one icebreaker is required for safe navigation (Šarlaj, 2015). An icebreaker provider carries out the formation of convoys.

[1] Federal State Institution "The Northern Sea Route Administration", www.nsra.ru.

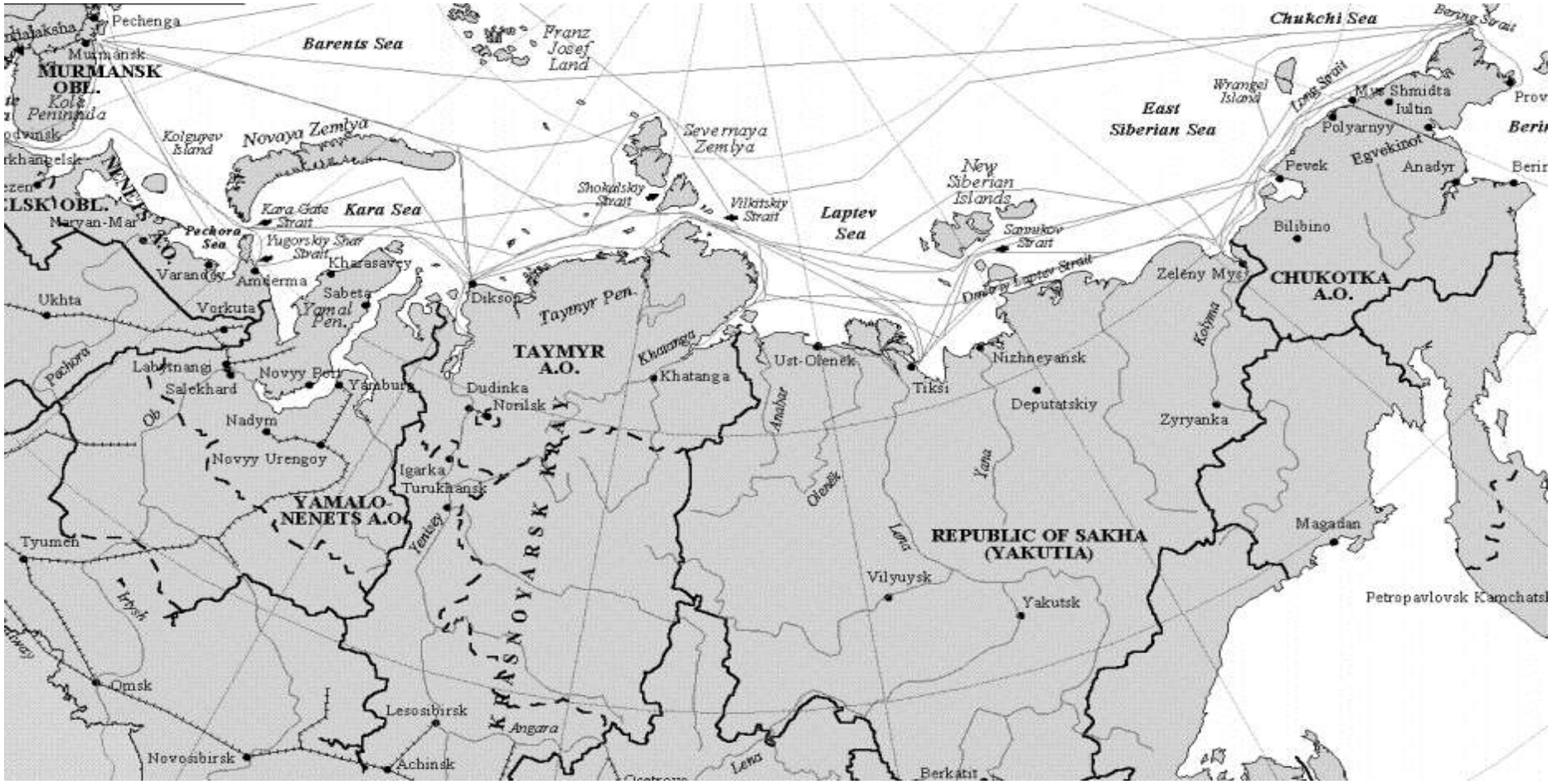

Figure 2.1 Passageways in the Northern Sea Route waters (*Source: Ragner, 2000*)

Ice class is one of the vessel's characteristics describing its ability to navigate in different types of sea ice conditions. The amount of icebreaker support, navigation route and the areas along the NSR where icebreaker support is required depend on the vessel's ice class and current ice conditions. The higher the vessel's ice class (expressed in numbers), the more challenging ice conditions the vessel can operate in. Russian ice class requirements are regulated by the Russian Maritime Register of Shipping (Russian Maritime Register of Shipping, 2015). It distinguishes between nine ice classes: Ice1-Ice3 and Arc4-Arc9 for merchant vessels, and four classes for icebreakers. For each ice class the following characteristics are defined: a description of waters the vessel type can navigate in, maximum ice thickness, ice age, and the period of navigation. Calendar year is divided into summer-autumn and winter-spring navigation periods.

The NSRA subdivides the waters of the NSR into seven zones: South West and North East parts of the Kara Sea, the Laptev Sea, and the East Siberian Sea, and the Chukchi Sea (The Northern Sea Route Administration, 2015b). The requirements for icebreaker support can be derived from the criteria for admission of vessels to the NSR provided in the Rules, see excerpt in Table 2.1. Table legend is explained as follows: IS – icebreaker support, IN – independent navigation, S – severe ice conditions, M – moderate ice conditions, L – light ice conditions, "+" – navigation permitted, "–" – navigation prohibited. Admission criteria are grouped by vessel's ice class and period of navigation given in months of the year (Rules of navigation in the water area of the NSR, 2013).

Table 2.1 Criteria for admission for navigation in the NSR (*Source*: *Rules of navigation in the water area of the NSR, 2013*)

Ships ice reinforcement class	Ice navigation mode	The Kara Sea		The Laptev Sea		The East Siberian Sea		The Chukchi Sea
		South-West part	North-East part	South-West part	North-East part	South-West part	North-East part	
		S M L	S M L	S M L	S M L	S M L	S M L	S M L
Arc4	IN	- + +	- + +	- - +	- - +	- - +	- - +	- + +
	IS	+ + +	+ + +	- + +	- + +	- + +	- + +	- + +
Arc5	IN	+ + +	+ + +	- + +	- + +	- + +	- + +	- + +
	IS	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +

Complete criteria for admission of merchant vessels are provided in the same format for vessels without ice reinforcement and vessels with class Ice1-Ice3 for the period of navigation from July to 15th November; and for vessels of ice class Arc4-Arc9 for the following periods: July to October, November to December and January to June.

2.3. Weather conditions

The NSR lies across areas with very harsh weather conditions: extreme low temperatures, long hours of darkness, strong winds, fogs, drifting sea ice and icebergs. Shallow straits, drifting sea ice, the presence of thick multiyear ice and pingos make navigation along the route very challenging.

The Arctic region has been seriously affected by climate change which resulted in significant sea ice reduction over the last 20 years. Sea ice thickness can be classified into three categories: new ice (up to 30cm), one-year ice (up to 1.6m), and multi-year ice (up to 3m). Drifting ice massifs (ice floes) and fast ice influence vessel's routing decisions. A smaller size flow can be circumvented, while larger floes often have to be navigated through. The most powerful icebreaker is able to break the ice up to 2.5 meters thick when moving across ice fields (Šarlaj, 2015).

From early June the seaways are mainly covered with one-year ice, which is broken easily and thus the choice of the route during the summer period is defined by the position of large drifting ice massifs. In September and October the NSR may be completely free of ice and a vessel can make a voyage from Novaya Zemlya to the Bering Strait at the speed of 14 knots just within 8 days (Northern Sea Route Information Office, 2015d). In November, when the summer-autumn navigation period comes to the end, the waters of the Laptev Sea and the East Siberian Sea are covered with new ice up to 30cm that nevertheless allows a vessel to pass the NSR with the assistance of an icebreaker. Between November and June when large areas are covered with fast ice the selection of navigation route is thereby determined by ice fields characteristics (thickness and age) and as well the capabilities of the icebreakers.

3. RESEARCH SETUP

3.1. Objectives of research

In our research, we define the throughput of the NSR as the fraction of transit orders satisfied during the period of navigation. The objective of this research is to develop a model for analysis of the NSR throughput with respect to the number of available icebreakers and the total number of orders for transit during navigation period taking into account ice conditions. The transit of vessels is simulated through modelling convoy formation and assignment of icebreakers to convoys according to the Rules. The model allows assessing the average delay time from the requested transit start date.

3.2. Assumptions and simplifications

This section presents assumptions and simplifications applied in the simulation model development.

Route selection. For simplification purpose we consider one NSR route and omit the procedure of route selection. The transit along the route is considered in both directions between the easternmost and westernmost points of the route.

Total number of transit orders. We assume that the forecast for the total number of transit orders is known for the whole period of navigation and for each month in both directions. We consider only transit orders for which icebreaker support is required in at least one zone of the route.

Ice conditions and icebreaker speed. We consider three types of ice conditions (easy, moderate and severe) according to the NSRA subdivision (The Northern Sea Route Administration, 2015b). For simplification purposes we assume that ice conditions only depend only on the ice concentration. We use the subdivision of the NSR into zones provided by the NSRA to determine the areas where icebreaker support is required. Ice conditions and speed are assumed to be constant for each month and NSR zone similar to assumptions in (Bergstrøm et al., 2015). Probability distribution of ice conditions is assumed to be known for

each month and the NSR zone (see for example Choi et al., 2015). Expected icebreaker speed is assumed to be forecasted as in Liu and Kronbak (2010).

Customer's decision making logic. The NSR throughput is constrained by the limited number of available icebreakers. Thereby queues of convoys awaiting an icebreaker may appear. Here it is important to consider how long a customer is ready to deviate from his schedule of transiting the route. Icebreaker provider informs the customer about the expected date of the start of the transit taking into account the planned convoy start date or/and the convoy queueing time. Each customer has his own preferences concerning the choice of the NSR for transit, which in addition may change over time. The choice is mainly determined by time savings, tariff levels, and other transportation costs. The choice involves resolving trade-offs when assessing transportation cost and time, and each customer has his own utility curve. At this state we omit the consideration of the economic aspects assuming that customer's choice is based only on the estimation of the transit start date and a customer-defined maximum delay time from the requested transit start date.

Convoy formation. We simplify the procedure of convoy formation assuming that a convoy is supported by only one icebreaker and there are a minimum and a maximum number of vessels in a convoy. Furthermore, we assume that there are several types of convoys in terms of vessels' ice class that can be assigned to them. For each month, combinations of vessel ice class that can be assigned to a certain type of a convoy may differ. The logic behind this assumption is that a vessel with the ice class Ice2, for example, can hardly sail the same route as the vessel with the ice class Arc5 at the beginning or at the end of the period of navigation when the ice conditions deteriorate. Therefore, in different time periods combinations of vessels that can be assigned to one convoy may vary.

Vessel's ice class. We assume that all vessels intending to transit the NSR have ice classes Ice2-Arc5 according to the Russian ice class specification, and that the discrete probability distribution of ice classes is the same in each month of the navigation period.

4. SIMULATION MODEL

In this section we present the description and logic of the simulation model, and how transit demands and ice conditions are modelled.

4.1. Data modelling

The number of transit orders for each month of the period of navigation is modelled as a fraction of the total number of orders. We consider the requested start dates of the transit orders as a Markov chain where the time intervals between the orders' requested start dates follow an exponential distribution. Vessel`s ice class is sampled from a discrete probability distribution.

The type of ice conditions is generated from the triangular probability distribution. Ice conditions are modelled for each month of the period of navigation and each zone of the NSR assuming that certain ice concentration values correspond to easy (0-10%), moderate (10%-50%) and severe (50%-100%) ice conditions.

4.2. Model description

The simulation model provides a representation of the NSR transit system accounting for the interrelationships of its components. The system's components are transit orders, icebreakers and convoys. As we study the transit of vessels that require icebreaker support, we consider a

transit order as part of a convoy. The state of the system is described by the state of its components. In discrete-event simulation, observations are gathered at certain discrete points in time when the state of the system changes. In the NSR transit system, we define the following occurrences as events: order generation, order cancelation, convoy generation, start and end of convoy movement, entering a new zone by a convoy or an icebreaker, and month change.

We define the number of available icebreakers and the total number of transit orders during the navigation period as the experimental design factors to evaluate the system's performance under the selected scenarios. Two evaluation criteria, the average delay time from the requested transit start date and the fraction of orders satisfied are used for the assessment of the system's performance.

4.3. Logic of the simulation model

The conceptual logic of the simulation model is visualized in Figure 4.1.

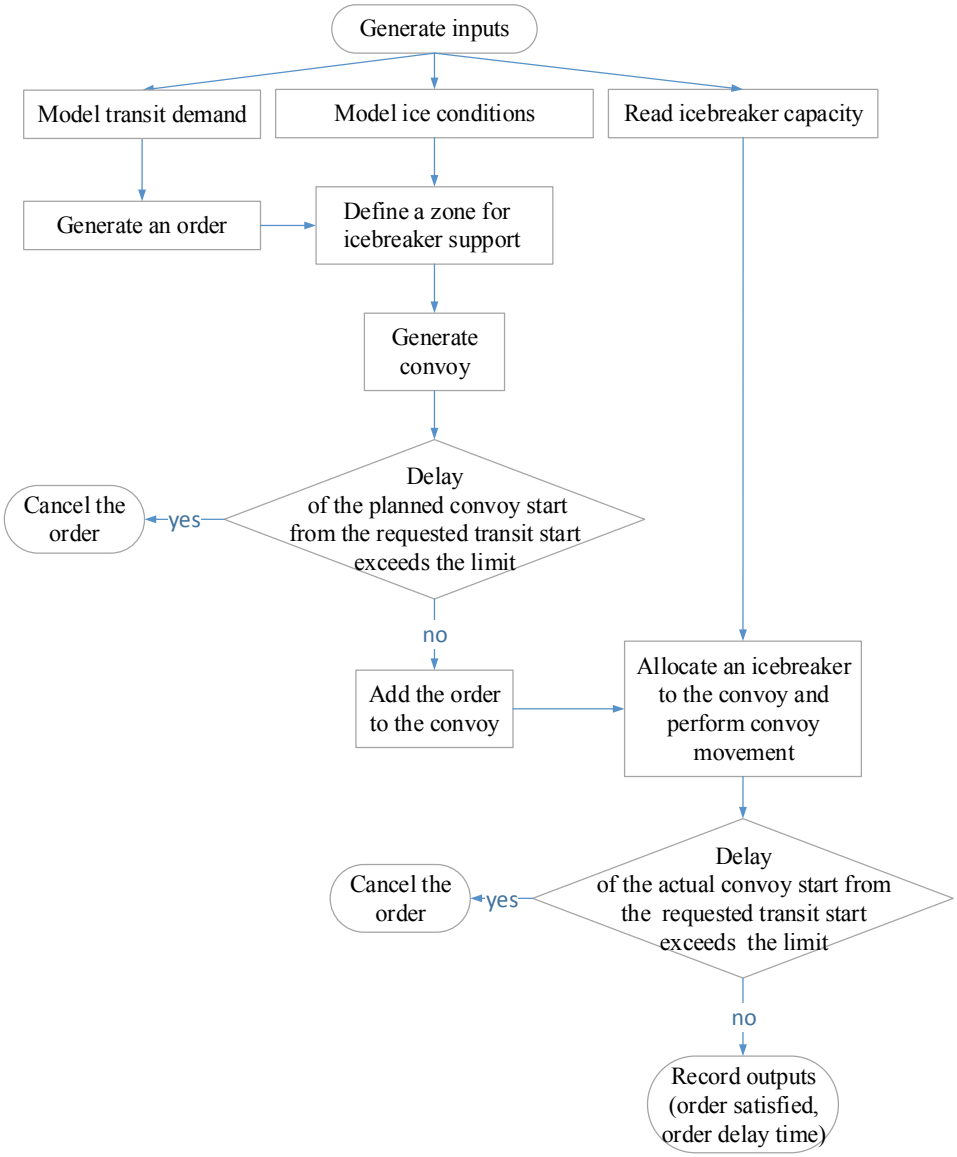

Figure 4.1 Conceptual logic of the simulation model

The logic of the developed simulation model includes two phases. The first phase involves the assignment of zones for icebreaker support and convoy generation. The second phase involves the assignment of icebreakers to convoys and the execution of convoy movements under icebreaker support.

For each transit order, a zone for icebreaker support is assigned based on the vessel`s ice class and the ice conditions in the month of the requested transit order start date. The transit orders are grouped in convoys as follows. An incoming transit order is assigned to a certain type of a convoy based on the defined zone for icebreaker support. If a convoy of this type is not already generated, the incoming transit order initiates the generation of a new convoy. The planned convoy start date is updated each time a new order is assigned to the convoy and determined by the requested start date of the last assigned transit order. The difference in time between the requested transit order start date and the planned convoy start date is compared to the maximum delay time for each new order. If the delay exceeds the maximum delay time, the order is cancelled. A convoy is considered to be fully generated when its size reaches the maximum limit.

The actual convoy transit start date may differ from the planned convoy start date when a convoy waits for an available icebreaker. When the information that there is an available icebreaker is received, the icebreaker is assigned to the convoy, and the zone(s) for icebreaker support are reassigned according to the ice conditions of the current month. Thereafter, the icebreaker moves to the convoy's start position. The actual convoy transit start date is defined by the arrival date of the icebreaker to the convoy's start position. The difference in time between the requested transit order start and the actual convoy start dates is compared to the maximum delay time. If the delay exceeds the maximum delay time, the order is cancelled. If the maximum delay is not exceeded, the icebreaker leads the convoy to the convoy's destination point. The icebreaker is then available for providing support to convoys waiting in the queue in the opposite direction (if any).

5. COMPUTATIONAL EXPERIMENTS

In this section we define the experiment setup, develop scenarios for computational experiments, describe general input data, and provide analyses of the results obtained.

The model was developed using Arena 13.0 discrete-event simulation environment software. Simulation model was run for 100 replications to obtain more accurate values of performance indicators.

5.1. Experiment setup

The aim of experiments is to analyze the impact of the change in the total number of orders arriving during the period of navigation and the total number of icebreakers on the two chosen evaluation criteria.

5.2. Description of scenarios

For the first experimental design factor, the total number of transit orders during the navigation period, we develop ten scenarios. The total number of orders increases from 70 to 700 at equal intervals. The minimum value corresponds to the number of vessels that navigated in the NSR waters during 2013 (Northern Sea Route Information Office, 2015a). With regards to the second factor, four scenarios with the number of available icebreakers ranging from three to six are considered. This is assumption corresponds to the Russian plans

on maintaining icebreaker support capacity (Pettersen, 2012). The total number of scenarios, taking into account all combinations equals 40.

5.3. Data generation

Navigation period. Officially, the normal navigation period lasts from the mid of July till the mid of November (Northern Sea Route Information Office, 2015a). In the experiments we consider the navigation period from the beginning of July till the end of November.

Icebreaker speed. Icebreaker speed is defined as a parameter with the triangular probability distribution for each zone of the NSR and for easy, moderate and severe ice conditions. The minimum, maximum and mode values of probability distributions are generated based on the information derived from Liu and Kronbak (2010).

Requested transit order start dates. The fractions of transit orders for each month of the navigation period are established in relation to the transit statistics of the Suez Canal (Suez Canal Authority, 2015).

Vessel's ice class. The parameters for the ice class discrete probability distribution are modelled based on the NSR transit statistics for 2013 (Northern Sea Route Administration, 2015a).

Ice conditions. Ice condition types are generated from the triangular probability distribution. The values for the minimum, maximum and mode of the ice concentration values for each month and each zone are generated based on the on information available from the Arctic and Antarctic Research Institute (2015).

Maximum delay time. As outlined in Section 3.2, the customers' decision concerning the cancellation of an order is based on the limit on the maximum delay of the actual transit start from the requested transit start. The limit is set to 15 days based on the difference in sailing times from Kirkenes, Norway, to Lianyungang, China, via the Suez Canal and via the NSR (Bergo, 2014).

Distances and waypoints. We consider the shortest possible route between Kara Gate and Bering Strait. The waypoints correspond to the borders of the NSR zones defined by the NSRA (Northern Sea Route Information Office, 2015e), eight in total. Distances between waypoints are calculated based on the waypoints' coordinates.

Convoy size. The size of convoy is generated from the triangular probability distribution with minimum, maximum and mode values generated based on the information on convoy formation provided by (Šarlaj, 2015).

5.4. Results

The fractions of satisfied transit orders for all developed scenarios are presented in Figure 5.1. Contrary to the expected results, no constant declining trend is observed. Instead, the fraction of orders satisfied for all icebreaker scenarios increases initially at a higher rate. For example, it grows from 60% to 90% for the cases with 5 and 6 icebreakers when the number of orders increases from 70 to 210 respectively. The trend in fraction of orders satisfied continues with a gentle decline (by 5% to 10% for each subsequent increase in total orders) for the number of orders exceeding 210 per navigation period. It can be explained by the following phenomena. With the small number of orders, the time intervals between the requested transit start days are relatively large. During convoy generation, the planned convoy start date may deviate significantly from the requested start dates of orders assigned to the convoy. This results in about 40% of orders being cancelled due to the exceeded limit on maximal delay.

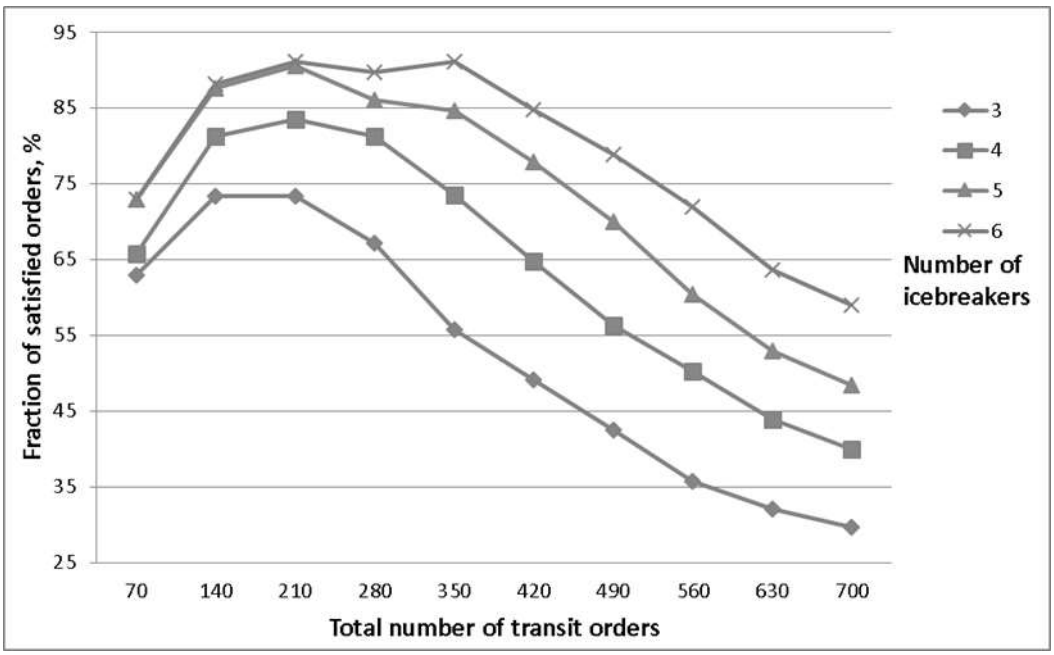

Figure 5.1 Fractions of satisfied transit orders

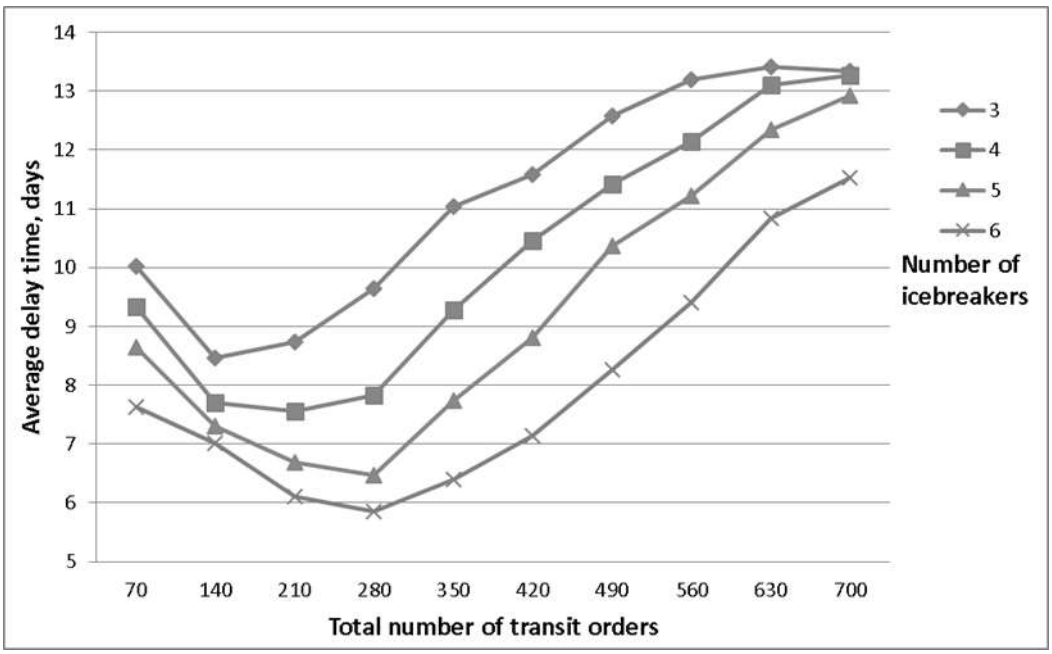

Figure 5.2 Average delay time from the requested transit start date

With the initial growth in the total number of orders (<210), the fraction of orders cancelled due to exceeded limit on maximal delay is reduced. This happens due to smaller deviations between the planned convoy starts and the requested transit starts of orders in the convoy. At the same time, the fraction of orders cancelled due to the deviation between the actual convoy start dates and the requested transit start dates is low due to sufficient icebreaker capacity and almost no waiting for available icebreaker. With the further increase in the total number of orders (>210), a smaller fraction of orders is satisfied due to more order cancellations explained by large deviations between the actual and the requested transit starts caused by more convoys and longer waiting time for an available icebreaker.

The dependence of the average transit delay time from the requested transit start date on the total number of orders and the number of icebreakers is visualised in Figure 5.2. The total transit order delay time is the sum of two possible delays: first, the delay from the planned convoy start to the requested transit start and, second, the delay from the actual convoy start compared to the planned convoy start. The planned convoy start is determined by the last transit order assigned to the convoy. With the small total number of orders and large time intervals between the requested start dates of transit orders assigned to convoys, the delays from the planned convoy start dates to the requested transit starts are relatively large. On the contrary, the delays from the actual until the planned convoys' start dates are insignificant due to sufficient icebreaker capacity. The average order delay time for the scenario with 70 orders and 3 available icebreakers is 10 days and is reduced to 7.5 days when the number of icebreakers is increased to 6. With the initial increase in the total number of transit orders (up to 210 in total) and shorter time intervals between the requested transit start days, the delays between the planned convoy starts and the requested transit starts in the convoys will reduce substantially. While the deviations between the actual and the planned convoy start dates may only grow slowly, resulting in the smaller total order delays and the average delays. With the continued increase in the total number of orders (>210), the total order delays start to increase due to a significant increase in the delays from the actual to the planned convoy starts thereby outweighing the reduction in delays from the planned and the requested starts. The average order delays for the largest number of orders converge to the maximal delay limit.

6. CONCLUSIONS AND FURTHER RESEARCH

This paper addresses the analysis of the NSR throughput under icebreaker support. The objective of the research is to define the main factors influencing the route's throughput (ice conditions, vessels ice class and speed, navigation rules for icebreaker support, number of icebreakers in operation, order processing logic, convoy formation, etc.), and to model the transit of vessels via the NSR. Discrete-event simulation is used as a methodology for the throughput assessment due to the stochastic components of the transit process.

The NSR has not yet been used at large scale therefore the historical transit data is not representative. The model of the transit process is developed based on the information obtained from the transit data and expert assessments obtained from open sources. It is tested on the simulated data taking the transits of the past few years as a starting point. Results of experiments on generated data show that the initial increase in the total number of orders leads to a substantial increase in the fraction of orders satisfied and average delay time reduction. Further increase in the total number of the transit orders changes the trend to the opposite. Obtained results confirm the expectations that the increase in the number of icebreakers in operation leads to a higher fraction of satisfied orders and shorter delay times.

The developed simulation model may have a value for the shippers and transport providers operating in the Arctic, and for the NSR Administration since it allows for the assessment of the average delay time from the requested transit start date and the NSR throughput for increased flows of vessels via the NSR and the various icebreaker fleet sizes. However, more advanced weather conditions and vessel speed modelling could be incorporated, and further investigation of the decision making logic related to convoy formation and order processing should be accounted for in further research.

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Cyber-Physical Systems (CPS) in Supply Chain Management – A definitional approach

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ABSTRACT

Purpose
The emerging technology of Cyber-Physical Systems (CPS) promises new problem solutions in manufacturing, logistics and SCM. In order to enable a structured scientific discussion, a general definition of such systems is needed.

Design/methodology/approach
To deliver such a definition, scientific articles on the relatively young research field of CPS have been identified and analyzed. Methods like literature review and matrix analysis have been applied during research work.

Findings
On an abstract level, seven basic functions of CPS have been identified. Besides these functions, several phenomenological characteristics emerged as well. Combining the functional and the phenomenological view, a generally applicable definition has been constructed. Some first application examples from logistics, manufacturing and general Supply Chain Management illustrate the definition.

Research limitations/implications
The paper aggregates findings from different research streams. They are application and technology agnostic. It would, in a next step, thus be necessary to identify the specific technologies behind those functions, to describe the state of the art from an application perspective, and to develop a framework for future research.

Practical implications
Considering the great potential of CPS within an operational context, this paper aggregates definitional aspects from a consistent scientific perspective. The processing of the literature on hand addresses a tangible demand for economic practice, which seems to be overwhelmed by the sheer amount of different terms and definitions.

Original/value
The presented study provides strong insights into the emerging subject of CPS gearing towards a prospective research-focus on operational aspects.

Keywords: Cyber-Physical Systems (CPS), Internet-of-Things (IoT), Supply Chain Management, Information and Communication Technologies (ICT), Literature Review

1. INTRODUCTION

National, pan-European and global operating companies are more and more forced to deal with the varying aspects of digitalization and its complementary developments and innovations in the field of information and communication technologies (ICT), such as the Internet-of-Things (IoT). Those manifestations of information technology are revolutionizing economic products, services and especially processes right up to new eras of competition and the redefinition of industry boundaries (Porter and Heppelmann, 2014). One relevant aspect concerning this development, particularly within operational processes, is the rise of so called Cyber-Physical Systems (CPS). The underlying research project primarily focusses on the meta-context of the Internet-of-Things, a "global network and service infrastructure of variable density and connectivity with self-configuring capabilities based on standards and interoperable protocols and formats which consists of heterogeneous things that have identities, physical and virtual attributes, and are seamlessly and securely integrated into the Internet" (Mazhelis et al., 2012, p. 1). It therefore consist of multiple physical objects, which are able to interact and cooperate with each other in order to reach common goals and create new applications through the use of modern wireless telecommunication (Atzori et al., 2010; Thiesse et al., 2011; Vermesan et al., 2013).

A Cyber-Physical System within this context uses "computations and communication deeply embedded in and interacting with physical processes to add new capabilities to physical systems." (Lee, 2009, p. 71). Such Systems therefore do integrate sensors and actors into physical devices, connect them with cyber components and, as a consequence, are capable of independent decision-making and of adapting intelligently to changing conditions (Sahingoz, 2013; Verl et al., 2012). That such systems do have the potential to bring along a wide variety of benefits for several aspects of modern Supply Chain Management appears to be pretty obvious. In case of product manufacturing, possible positive impacts can among others be predicted within asset management, assembly and manufacturing automation, as well as supporting product life cycle management (Wright, 2014). Furthermore, new problem solutions in logistics and Supply Chain Management, for instance in case of decision support, visibility and Supply Chain Event Management, emerge as well (Lang et al., 2011; Ivanov and Sokolov, 2012; Sarac et al., 2010). In the current discussion of Cyber-Physical Systems, so called Wireless Sensor Networks (WSN) - "product[s] of the convergence of sensing, computation and communication into cubic centimeter sized devices" (Ota and Wright, 2006, p. 3) - are in the focus of research-attention with other congeneric technologies, such as Radio-Frequency Identification (RFID), to be practical possibility (Ivanov and Sokolov, 2012; Sahingoz, 2013). Technologies of this type go in line with the paradigmatic changes concerning so called 'smart objects' (Porter and Heppelmann, 2014; Sanchez Lopez et al., 2011). They can be seen as fundamental components to the realization of the Internet-of-Things and do therefore serve as enabling technologies for Cyber-Physical Systems (Fleisch, 2010; Ngai et al., 2008; Sanchez Lopez et al., 2012).

Due to the great potential of Cyber Physical Systems, it becomes necessary to determine what such systems actually are and to furthermore identify their achievable benefits. These aspects have already found a decent amount of recognition – mostly within practical papers (white papers, technical reports, etc.) addressing topics such as 'Industry 4.0' and the 'Industrial Internet'. Economic practice therefore seems to be way ahead of the more theory-oriented scientific community. Nevertheless, highly specialized academic journals also started to draw a decent focus on the upcoming research stream of Cyber-Physical Systems. The objective of this contribution therefore is to aggregate already existing findings and to develop a generally applica-

ble definition of the wording Cyber-Physical Systems from a more consistent scientific perspective. In order to serve that purpose, a concept-centric *Literature Review* was conducted aiming at presenting a systematic overview over the relevant literature published.

Therefore, four research questions were raised:

- How does a general applicable definition of the term Cyber-Physical System(s) look like from a consistent scientific perspective?
- Which basic functions and phenomenological characteristics are most suitable for describing Cyber-Physical Systems on an abstract level?
- What are the most common specific enabling technologies behind those functions?
- To what extent do such systems and technologies provide new problem solutions in manufacturing, logistics and Supply Chain Management and how can those solutions be illustrated by application examples?

This contribution is divided into five chapters. After introducing the topic, the second chapter starts with a general overview of CPS-related literature. The third chapter defines the methodological approach of the underlying Literature Review, while chapter four recapitalizes the results of it. Finally, the fifth chapter evaluates the essential findings and implications for further research are given.

2. GENERAL OVERVIEW OF RELATED LITERATURE

At this moment in time, CPS-literature is strongly two-parted. As mentioned previously, economic practice is already developing a certain understanding of what CPS actually are and how they will affect the economy of the future. Within this context, there are primarily two different keywords accompanying CPS-research, 'Industry 4.0' and the 'Industrial Internet'. These two terms can be used interchangeably to the greatest possible extent with the first one mainly representing endeavors of German government agencies or other comparable research authorities and the second one receiving more attention primarily within the United States and other Anglo-American research communities (Bruner, 2013; Lasi et al., 2014). Conveniently, the term Industry 4.0 will be used within this contribution, considering it moreover as the 'manufacturing vision' of the Internet-of-Things. Publishers of such 'practical papers' are the "Association for Electrical, Electronic & Information Technologies (VDE)", the "Association of German Engineers (VDI)", the "National Institute of Standards and Technology (NIST)", or diverse institutions of the "Fraunhofer-Society", to name but a few (Kagermann et al., 2013; National Institute of Standard and Technologies, 2013; Spath et al., 2013). The presence of such a broad variety of prestigious R&D-societies once again shows the huge potential and relevance, ascribed to the potential research stream. Contributions do mainly focus on economic aspects of the current developments in case of potential benefits, applications, or use cases. Targeted industrial sectors are primarily transportation/logistics and manufacturing, but also Health Care, Energy and Infrastructure. Some of these practical papers do furthermore find themselves trying to verge on a definition of the underlying terms, among them naturally also Cyber-Physical Systems. A much noticed study of the German "National Academy of Science and Engineering (acatech)" for instance identifies several definitional functionalities of Cyber-Physical Systems (Geisenberger and Broy, 2012; Hellinger and Seeger, 2011). Such approaches might provide mostly

suitable insights to what such systems are from an economic and practical perspective, but they lack a measure of scientific resilience and reliability.

In respect of the scientific CPS-literature, terms like Industry 4.0 - and to a certain extent even the Internet-of-Things - stay mostly unnoticed. Furthermore, a broad variety of scientific disciplines such as electrical and mechanical engineering, (business) informatics, information systems, industrial safety, and business research are currently contributing to the upcoming research stream. Within many of these fields, fundamental work designing and developing Cyber-Physical Systems is provided. Not least, the "Institute of Electrical and Electronic Engineers (IEEE)" and the "Association for Computing Machinery (ACM)" distinguish themselves within rather scientific research and publication efforts. These papers do also deliver a decent amount of definitions, each one suitable for its own specific context. Therefore, according to the broad variety of different fields of research observing Cyber-Physical Systems, an equally broad variety of definitions arose. This leads to the realization, that, as well as economic practice, scientific literature is equally far away from providing a generally applicable and consistent definition of the CPS-term. Following this statement, the underlying field of interest can be considered as an ideal topic, which "is one where a number of conceptual and empirical articles have amassed without previous review efforts or a synthesis of past works" (Short 2009, p. 1312).

3. RESEARCH METHODOLOGY

In order to identify what Cyber-Physical Systems actually are and to enable a consistent wording, the aim of this study is to gain further insights into the current state of CPS research with a particular focus on defining Cyber Physical Systems. In addition to that, enabling technologies are brought into focus. In order to gain an overview and to collect relevant literature, a concept-centric *Literature Review* following Webster and Watson's approach was conducted (Webster and Watson, 2003). This procedure is not only valid for mature topics, where a broader variety of literature exists, but also for tackling "an emerging issue that would benefit from exposure to potential theoretical foundations" (Webster and Watson, 2002, p. xiv). By following this approach, the difficulty of a comparatively young field of research could be eluded.

Publication of CPS-related literature traceably started during 2008 and 2009 with Edward A Lee's efforts and endeavors concerning Embedded Systems in general and later on Cyber-Physical Systems in particular (Lee, 2008; Lee, 2009). A more accurate dating is hardly possible from today's perspective. Therefore, the underlying research can be considered as relatively recent with higher levels of publication activity starting no earlier than 2011. According to this fact, a 5-year time frame from 2009-2013 can be assumed as representative of scientific CPS-literature and therefore will serve as the scope of investigation. The chosen time frame also copes with the requirement of a relatively complete census of relevant literature (Webster and Watson, 2002). *Figure 3.1* shows the development over the observed period concerning publication quantity. The continuously rising number of publications over the recent years suggests, that the research stream concerning Cyber-Physical Systems is still emerging. Scientific literature has nevertheless already brought up a notably amount of valuable research, so that an aggregation of scientific contributions has the potential of providing relevant insights. In order to meet the requirement of providing a consistent scientific perspective on the field, practical papers as well as textbooks, news reports, master/bachelor theses and doctoral dissertations have been excluded. This exclusion follows the assumption, that journal-contributions are the most suitable and reliable source of information and new findings (Ngai et al., 2008). Furthermore, unpublished (working) papers, editorials and comments have been eliminated as well. Regarding the fact, that there is no rigid structure suitable to every single review (Salipante et al., 1982), these adaptions seem reasonable in comparison to analogous research endeavors.

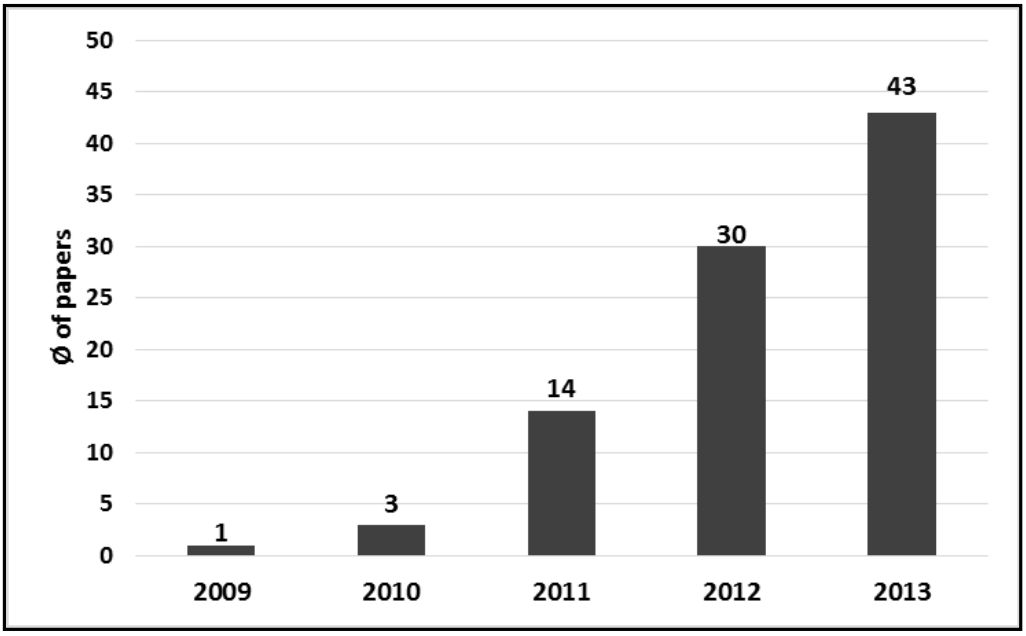

Figure 3.1 *Number of papers published (per year)*

Besides the conjuncture of a relatively young research stream, the relevant literature is also dispersed over a wide range of journals. Therefore, a pre-selection of and initial restriction on a certain spectrum of journals would be unrewarding due to the high potential of excluding relevant papers. With this in mind, the widest possible range of publications was investigated by using the following electronic databases.

- EBSCO Business Source Complete
- Emerald Insight
- Journal STORage (JSTOR)
- Science Direct
- Springer Link

The literature search was based on the term *"cyber physical systems"*, bearing in mind *Title*, *Abstract* and *Keywords (Subject Terms)*. Subsequently, duplications and non-English speaking publications have been removed. In a second step, the abstract of each paper was examined in order to eliminate such papers not directly related to the scope of research. Furthermore, the complete text of each article was reviewed excluding further irrelevances. This step was necessary to avoid uncertainty about the relevance of borderline publications. Nevertheless, if any uncertainty remained after the sampling process, the paper in question remained included. Finally, a total of 91 papers could be identified being published in 57 journals with only 14 of them publishing more than one related paper. Furthermore, only 3 journals were accountable for 5 or more relevant publications. This broad variety of academic contributions states the initial assumption of the underlying literature serving as a comprehensive base for further investigation of CPS-research.

Within the investigation of the literature sample, resulting from the initial search terms, sharper focus was placed on such papers carrying out a specific definition of what Cyber-Physical Systems actually are. The amount of such contributions sums up to a total of 38. In order to gain insights into the several specific components of the different CPS-definitions, and in a second step also into the use of specific enabling technologies, a *Matrix Analysis* following Salipante et al.'s approach - in the adaption of Webster and Watson - was conducted (Salipante et al., 1982; Webster and Watson, 2002). This procedure usually results in the compilation of a concept matrix, consisting of two different dimensions (with several sub-dimensions possible). The first dimension commonly identifies the relevant papers containing findings and the second one displays the findings themselves. The objective of this procedure is to identify clusters or patterns within a certain sample of studies. In the case of consideration, two mostly independent matrixes had to be synthesized. On the one hand, the various CPS-definitions, and on the other hand the specified enabling technologies, were structured in this manner. The results of these assembling and synthesizing processes are shown and discussed in *chapter 4*.

In order to avoid biases concerning the compilation of the concept matrix, the results were discussed by a team of two independently operating researchers. If there were any inconsistences coming up, the certain aspect had to be set under further review until a consensus was achieved (Ngai et al., 2008). Already beforehand, selection criteria were thoroughly and jointly elaborated in order to minimize inter-reviewer differences in findings (Salipante et al., 1982). These steps were of particular importance within the consolidation of discovered patterns resulting in the final functional clusters of Cyber-Physical Systems. By following the research methodology as explained, it can be assumed that further biases have been prevented as well.

4. DISCUSSION OF RESULTS

According to the depiction of the review methodology, results derived from the original set of literature can be subdivided into two different parts, still strongly affiliated with each other. These results are specified within *chapter 4.1* and *chapter 4.2*. Furthermore, *chapter 4.3* illustrates the outcomes with a set of descriptive application examples from manufacturing, logistics and general Supply Chain Management.

It has to be mentioned, that there is currently only a strongly limited amount of scientific papers on hand, directly addressing SCM-aspects of Cyber-Physical Systems. Due to that fact, the investigation remained in a first step open towards rather 'general' aspects of Cyber-Physical Systems as well. This leads on the other hand to a higher amount of scientific disciplines potentially benefiting from these research efforts. Nevertheless, SCM-specific considerations were hold in mind at any time leading to a SCM-oriented interpretation of results. In the further course of investigation, a keen focus on aspects concerning manufacturing, logistics and Supply Chain Management – especially with regard to enabling technologies and specific application examples – has been achieved.

4.1. Defining Cyber-Physical Systems

Initially, a generally applicable definition of the wording Cyber-Physical Systems – not only from a Supply Chain Management's perspective – has been developed. This definition results from a modified matrix analysis investigating 38 different definitions of Cyber-Physical Systems, obtained from the available scientific literature. Only at a first glance, these approaches differ greatly from each other. After a closer look, there are actually several similarities to be derived.

Main features of Cyber-Physical Systems are therefore the automated *integration* of physical and digital components, the enclosing monitoring of the physical reality through *sensors*, and the possibility to act upon this reality through *actors*. Furthermore, the embedded *processing of information and data*, as well as capabilities of *autonomous decision making and control*, are essential functions. Finally, Cyber-Physical Systems should contain the technical capabilities to communicate and coordinate with each other, as well as with associated information systems and with human authorities, and to respond dynamically and intelligently to changes within the physical world thereby improving their abilities, experience and knowledge *(networks)*. *Table 4.1* briefly explains these similarities, derived during the investigation of the literature sample.

Table 4.1 *Functions and characteristic attributes of Cyber-Physical Systems*

Function	**Characteristic attributes**
integration	CPS do integrate components of the physical and the virtual world, both inside a company as well as in cross-company contexts. Basal at this juncture is the precise and automated identification of physical objects.
sensors	CPS are capable of an enclosing monitoring of the physical reality by the use of sensors, e.g. for temperature, pressure, location, etc.
information and data processing	CPS do own the technical preconditions of processing data and information. In so doing, Microcontrollers and Microprocessors are essential elements of such systems.
automation and control	CPS do partially operate based on their own intelligence and are therefore capable of autonomous decision making beyond central instances or decision rules and of controlling the physical world.
networks	CPS do own the technical capabilities in order to communicate and coordinate themselves with other Cyber-Physical Systems, as well as with already existing information systems, and also with human users and decision makers.
actors	CPS sporadically control physical entities via actuators and do thereby affect processes in an active and physical manner. This capability is of particular importance within the context of robotics applications.
adaptability	CPS are, dependent on the respective context, capable of responding intelligently to dynamic changes and of improving their abilities based on own experience and knowledge.

It can therefore be summarized, that *seven functional clusters* emerge from the various definitions concerning Cyber-Physical Systems. These attributes do show different quantities of indication during the observed literature, as described in *Figure 4.1*, but they are nevertheless equally eponymous for defining what such systems actually are.

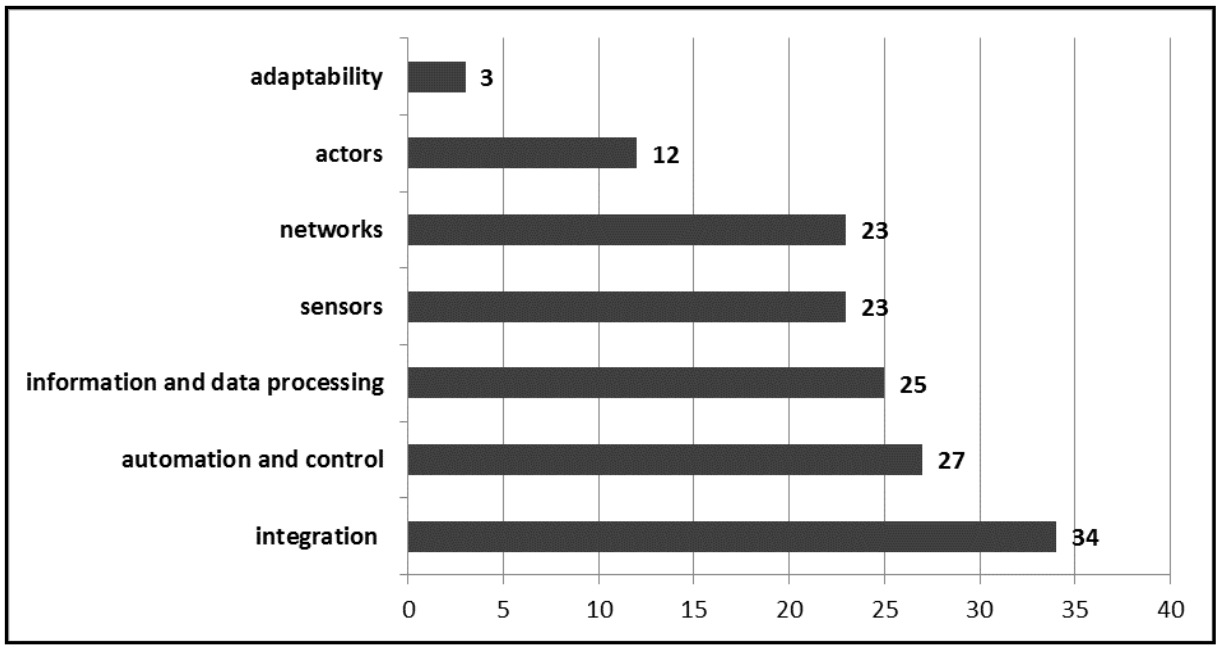

Figure 4.1 *Fequency of indication regarding CPS-functions*

Besides of the functional clusters already elaborated, several *phenomenological characteristics* emerged as well. Essential for almost every definition examined is the *decentralized management and control* of relevant processes, preferential directly on the object. This characteristic can only be achieved through the *embeddedness of Microelectronics*, directly into the physical processes and objects. In connection with the use of actuators, the importance of real-time capabilities emerges as well. In that case, a *deterministic behavior* of Cyber-Physical Systems becomes necessary. Furthermore, the terminology *'Big Data'* is emerging more recently. In a series of sensor-related CPS-applications, large amounts of heterogeneous data are generated. Those datasets have to rapidly be evaluated and analyzed in order to generate value for the operator/user.

Pulling together all these different functional aspects and phenomenological characteristics of Cyber-Physical Systems, a general applicable definitions can be composed. With respect to the different possible frameworks and contexts of application, a distinction between a broader and a narrower sense is made. *Figure 4.2* shows exactly these two approaches.

CPS in a broader sense: 'Cyber-Physical Systems' are (among themselves) interconnected and networked embedded systems. They monitor, govern and control the physical world via sensors and integrate the obtained data into the virtual (informational) world.

CPS in the narrower sense: 'Cyber-Physical Systems (CPS)' are distributed, (among themselves) interconnected, networked embedded systems using real-time communication. They monitor the processes of the physical world via sensors, govern and control them through actors and integrate the obtained data into the virtual (informational) world. CPS also distinguish themselves by a high level of adaptability and by the accomplishment of mastering complex data structures.

Figure 4.2 *Defining Cyber-Physical Systems*

4.2. Enabling Technologies

Subsequent to the definitional aspects of the review results, enabling technologies became apparent to be worth a further view. Therefore, the original sample of 91 scientific contributions was reinvestigated, with a special focus on technological aspects concerning CPS-realization.

According to the literature reviewed, Radio-Frequency Identification (RFID), Wireless Sensor Networks (WSN), Real-Time Location Systems (RTLS) and conventional Telematic Modules come into question as such technologies. These results do - to a greatest possible extent - confirm the insights from economic practice within the relevant fields of application concerning the Internet-of-Things, namely manufacturing, logistics and Supply Chain Management (Lempert and Pflaum, 2012; Majordomo et al., 2011; Sanchez Lopez et al., 2011). Near Field Communication (NFC) remains unmentioned, but might provide future potentials to that end as well, as it can be seen as a congeneric and functionally equivalent technology to Radio-Frequency Identification (RFID) (Harris et al., 2015; Violino, 2014). As *Figure 4.3* shows, only a partial quantity of the literature sample provides specific information on such mature and field tested systems. In addition, scientific literature furthermore points a keen focus on the terminology of application-specific Embedded Systems in general. With that in mind, any given enabling technology could be suitable depending on the specific context of the researcher. With respect to the physical objects being embedded with such technologies (and thereby becoming smart objects), the scientific literature remains unlimited to a broad variety of potential use-cases, likewise depending on the corresponding research focus. With regard to the research focus of this study, vendor parts, semi-finished and finished products come into question as a target of embeddedness as well as transportation boxes, capital goods, vehicles or entire assembling lines and buildings. Common to all examined contributions in turn is the subsequent attachment of the microelectronic elements to the objects on the one side or the integration into the respective object on the other side.

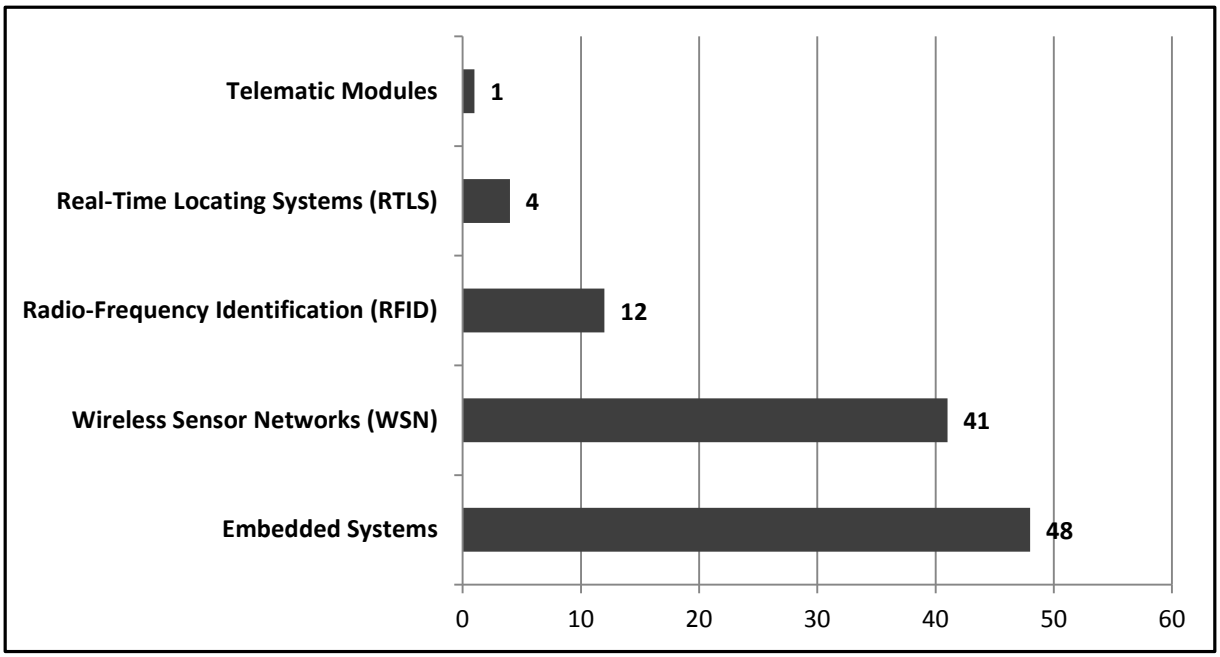

Figure 4.3 *Fequency of indication regarding CPS enabling technologies*

4.3. Applications of Cyber-Physical Systems

As a third pillar of this study, the rather abstract and seldom fuzzy-seeming results concerning functionalities and characteristics of Cyber-Physical Systems are illustrated by a set of descriptive application examples from manufacturing, logistics and general Supply Chain Management. The publications building the foundation for the subsequent elaborations are inconclusively direct results derived and obtained from the original literature sample. They are nevertheless expedient and strongly linked to the review results emerging from previous elaborations and do furthermore illustrate the linkage between the various enabling technologies and the specific CPS-functions.

Once again, it can be stated, that the embedding of microelectronic elements constitutes a fundamental requirement for the realization of Cyber-Physical Systems in general and therefore also for the Internet-of-Things. Cyber-Physical Systems themselves on the other side do not solely contribute to problem solving in such contexts. They furthermore have to be integrated into a specific application context. Several examples for such individual contexts related to the different enabling technologies are shown in the following

The usage of *Radio-Frequency Identification (RFID)* spans over a wide variety of applications within operational contexts. In manufacturing for instance, fundamental implementations are already established over a longer period. Such initial applications primarily encompass the automatic identification of products and other relevant objects over relatively short distances, e.g. within firmly linked assembling lines. Besides of the sheer task of identification, data capturing and storage capabilities became feasible as well. In more recent years, novel and innovative RFID-systems emerged providing further potentials, especially within monitoring, automation and controlling functionalities, leading to the enhanced integration of material and information flows. In this context, the profound support of warehousing operations became possible by way of example (Lim et al., 2013). Under such a scenario, the assistance of a broad spectrum of warehousing processes, up to a fully automated warehouse management, moved within the realms of possibility (Dimitropoulos and Soldatos, 2010).

Near Field Communication (NFC) can, as already stated in *chapter 4.2*, be seen as a congeneric and functionally equivalent technology to RFID. It provides, under some circumstances, even more extensive functionalities due to its origins within mobile payment. It therefore allows the clear identification of objects and humans, enables a "quick and easy wireless data transfer within close proximity" (Harris et al., 2015, p. 95) and is possibly even perceived to be the 'next step' within an automatic identification context. This does not necessarily imply the replacement of RFID-related business applications, but at least the potential to complement RFID-enabled processes (Harris et al., 2015; Violino, 2014). Physical objects, embedded with Microelectronics in the sense of NFC-technology, therefore do not only allow the integration of material and information flows but also information and data processing capabilities, maybe in the sense of maintenance operations, in which a communications interface between machineries and repairmen is necessary (Karpischek et al., 2009; Violino, 2014).

Existing *Real-Time Location Systems (RTLS)* do primarily serve the purpose of position determination within given and limited areas. They do exhibit a strong connection to the RFID-technology. This aspect is due to the fact, that the Microelectronics embedded usually are provided through RFID-tags or at least through strongly congeneric appliances (Ferrer et al., 2011; Thiesse and Fleisch, 2008). Alternatively, a combination with other already available communication networks, such as GPS or Wi-Fi, can be realized (Schrooyen et al. 2006). Current usage of RTLS-technology is commonly taking place inside of more or less highly complex manufacturing processes, such as wafer fabrication facilities. Inside of these application contexts, internal transportation and transfer processes are surveilled almost 'inch-perfect' and do allow

the management of waiting queues, the prioritization of waiting lots and the reduction of overall cycle times (Thiesse and Fleisch, 2008). Another application example is the combination with aspects of wearable computing for the purpose of assuring and localizing proper protective equipment for hostile or security-related vicinities (Barro-Torres et al., 2012).

In case of *Wireless Sensor Networks (WSN)*, a particular focus is set on the gathering of environmental parameters and on the ICT-related connectedness between separate objects. In contrast from RFID- and RTLS-technologies, sensor nodes do communicate and interact with each other, not only with their backend infrastructure. Information do find their way through a system by the use of modern communication and networking protocols, until they reach a random Gateway and as a consequence the informational backend (Ota and Wright, 2006). This procedure allows a flexible and cost-efficient communication infrastructure, by which especially transparency can be brought into any given logistics network. Beyond that, a rough localization of the certain objects can be provided as well. Target of such localization and transparency efforts are among others currently seen in environmental-sensitive supply chains, which would for instance benefit from the continuous monitoring of the ambient temperature (Hafliðason et al., 2012; Raab et al., 2011). Another example for WSN and the beneficial use of sensor data can be illustrated through so called 'wide-area traffic monitoring' processes, in which sensor nodes are used to capture traffic movements inside of a logistics center (Bottero et al., 2013).

The usage of *Telematic Modules* is already well known over a longer period of time for the usage within surface freight and container logistics. Complex microelectronic labels, among others containing GPS-, GSM- and sensor-modules, are broadly used to monitor and control international supply chains (Lang et al., 2011). Such 'intelligent containers' do serve as an autonomous supervision system, which is meanwhile capable of decentralized data-processing and of the generation of the required energy from its environment, e.g. through solar panels (Jedermann et al., 2007; Lang et al., 2011). Through current and future developments of miniaturization and deeper integration into the objects of the material flow, additional use cases like parcel-monitoring and the surveillance of global machinery and other capital assets are also gaining feasibility. More recently, applications within urban logistics are becoming more important as well (Walker and Manson, 2014).

Conclusively, application-specific *Embedded Systems* require a further look. Meanwhile, a whole string of technology platforms for the development and customization of such systems exists. These platforms are subject to constant and consequent advancements, aiming at an efficient and effective development of complex, sophisticated and foremost context specific Cyber-Physical Systems. Such Embedded Systems do provide a most extensive range of functions, including the capability to autonomously govern processes, and do therefore, beyond other technologies, require deterministic behavior especially in case of information and data processing and networking. Design challenges currently reside, among others, in terms of flexibility, robustness and reliability (Prasse et al., 2014). A specific application example would be an intelligent storage bin, allowing the automated gathering, forwarding and processing of relevant data as well as the autonomous triggering of logistical (e.g. replenishment) processes necessary (Prasse et al., 2014; Würth Industrie Service, 2015).

The previous elaborations do not only illustrate the broad variety of applications concerning CPS enabling technologies, but do also provide a certain impression about new and existing problem solutions being practical possibility within an operational context. *Table 4.2* gives an overview over the particular technologies and illustrates, to what extent the functional profile of an ideal-typical Cyber-Physical System is met.

Table 4.2 *CPS-functions of enabling technologies*

enabling technologies	CPS-functions						
	integration	automation and control	information and data processing	sensors	networks	adaptability	actors
Radio-Frequency Identification (RFID)	x	x					
Near Field Communication (NFC)	x	x	x				
Real-Time Location Systems (RTLS)	x	x	x	x			
Wireless Sensor Networks (WSN)	x	x	x	x	x	x	
Telematic Modules	x	x	x	x	x	x	
Embedded Systems	x	x	x	x	x	x	x

5. CONCLUSION, IMPLICATIONS AND OUTLOOK

The research efforts behind this contribution succeeded in determining what Cyber-Physical Systems actually are. They therefore generate a universal understanding of the terminology meeting the requirements of general applicability and consistence. Furthermore, appendant enabling technologies have been identified. In addition, some first application examples from manufacturing, logistics and Supply Chain Management have been provided more profoundly establishing the linkage between theory oriented methodological aspects - in terms of functionalities and phenomenological characteristics - and practical aspects of actually implementing Cyber-Physical Systems and providing new problem solutions. It therefore can be stated, that the scientific fundamentals of the comparatively young field of Cyber-Physical Systems have been properly reviewed and analyzed. The ancillary synthesis of theoretical foundations and backgrounds allows the establishment and continuation of this upcoming research stream. By doing so, the scientific community gains the opportunity to catch up with economic R&D activities. The processing of the scientific literature on the other hand furthermore addresses a tangible demand for economic practice, which seemed to be overwhelmed by the sheer amount of different terms and definitions.

Limitations of the study might be rooted in the comparatively strong focus on technological aspects of Cyber-Physical Systems. The findings, aggregated from different research streams, are primarily application and technology agnostic. Beside of these undisputable significant aspects, addressed in most of the scientific papers reviewed, the user's side of CPS-applications also requires keen attention. In addition to physical and microelectronic objects and applications, human users and decision makers are of particular importance. Such operators as owners of 'things' do articulate specific needs and requirements during the whole life-cycle of a system. Additionally, service organizations from within or outside respecting companies are relevant. These organizations do offer solutions using information and communication technology (ICT), addressing problems and needs. By summing up all those CPS-related solutions and services, a detailed picture of Cyber-Physical Systems in particular and of the Internet-of-Things as a whole - in the sense of a descriptive framework - can be drawn (Prockl and Pflaum, 2013).

Another limitation might reside within the still emerging field of research concerning Cyber-Physical Systems. Due to the persistently rising number of publications, it might at a future date become necessary to adapt the current 'snapshot in time' with respect to potential definitional and technological changes. As a last limitation, the focus on scientific literature, in the form of journal-contributions, might be questioned. It therefore potentially promises further insights, apart from the exposure of potential theoretical foundations, to extent the underlying research framework towards other data sources, such as dissertations, working papers, or technical reports.

As previously mentioned, this study provides comparatively new and relevant aspects concerning Cyber-Physical Systems, especially from a functionally abstract and phenomenological point of view. In a next step, the rather user-oriented perspective on the Internet-of-Things therefore deserves further attention. It would moreover be of scientific value to further enhance the level of detail concerning the technological viewpoint. Following this assumption, not only enabling technologies, but also complementary and congeneric innovations, such as the Internet of Services, Mobile and Cloud Computing, as well as Big Data Analytics and the digitalization of Social Networks, might be of interest. Finally, future endeavors in CPS-research might also target towards the further conceptual integration into the Internet-of-Things and therefore as well within the scientific field of digitalization, meant as "the transformation of socio-technical structures that were previously mediated by non-digital artifacts or relationships into ones that are mediated by digitized artifacts and relationships." (Yoo et al., 2010, p. 6). This mindset once again states the assessment, that such processes go beyond technological aspects and also involve socio-technical structures.

It can recapitulatory be registered, that the underlying contribution only scratches the surface of the potentials for CPS-related research. It nevertheless provides several relevant insights into a comparatively new field of interest bearing the potential of helping to establish a new research stream aiming towards operational aspects of Cyber-Physical Systems.

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PRACTICES IN THE WINE SUPPLY CHAIN

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ABSTRACT

Purpose
The low level of supply chain maturity and the lack of industry best practices in wine supply chains are stated to be some of the biggest challenges for this industry. The aim of this paper is, therefore, to explore practices in the wine supply chain, and to evaluate a framework of supply chain practices through a multiple case study.

Design/methodology/approach
A multiple case study approach is used, through which the case of a multi-national wine producer is compared to the supply chains of small Australian winemakers.

Findings
The findings corroborate that performance, while highlighted in production and the quality of the product, is less in focus in terms of efficiency and effectiveness in the supply chain. The wine supply chain is very manufacturing and marketing-focused, with distribution supporting these activities. The case study shows that supply chain practices such as customer orientation, process integration and visibility are key to the wine supply chain, albeit they are not discussed in supply chain terms.

Research limitations/implications (if applicable)
The research indicates the link between supply chain practice and performance, yet the directionality of this link remains to be established.

Practical implications
Wine researchers have called for more research in supply chain management. This paper aims to fill this gap and in addition provide practitioners with practice examples.

Social implications
-

Original/value
This paper is a first evaluation of a conceptual framework on supply chain practices in the wine supply chain. This framework is very useful for eliciting current practices but also for benchmarking with other companies in the wine industry.

Keywords: Supply chain practices, supply chain, wine supply chain, best practice, competitive advantage

1. INTRODUCTION

The wine industry is proud of having a long history. Even "new wines" and "new world wines" are from areas where wine has been grown by now for centuries. More recently, wine has been started to be cultivated also in various Asian countries, predominantly in China, there are new growers in various countries in Africa and also more and more Latin American countries are interested in growing wine. Also climate change impacts on the locations where wine can be grown. Apart from these developments, the industry is impacted largely by trends in alcohol consumption but also changes in preferred tastes (Douglas, 2012). Furthermore, consumers have started to put more emphasis on various aspects of sustainability in the wine industry (Golicic and Smith, 2013), e.g. its carbon and water footprints (Pattara *et al*., 2012; Christ, 2014). Such a change in emphasis and expectations is expected to alter supply chain practices.

In spite of the history and also the size of the global wine industry, which for 2013 has been estimated to 25.7 billion EUR (OIV, 2014), and in spite of the sizeable research efforts put into growing, production, and even wine marketing, each of which have dedicated journals, from the *American Journal of Enology and Viticulture* to the *International Journal of Wine Marketing*, there is considerably less research on wine supply chains. At the same time, the success of the industry depends not just on the quality of the wine, but also, how the wine reaches consumers, which is, according to Kumar *et al.* (2013, p.1078), "one of the longest supply chains in the world". The very length of routes has been investigated in terms of the impact of ports and choices in transportation modes on the wine supply chain (Moccia, 2014). But the supply chain also impacts on the quality of wine, as Ting *et al.* (2014) emphasize in light of the cold chain. Not surprisingly, literature has come to highlight the importance of supply chain relationships (Wilson and Goddard, 2004; Thah and Olsen, 2006; Steiner, 2012; Kumar *et al.*, 2013) as well as traceability (Cimino and Marcelloni, 2012; Ting *et al.*, 2014).

The wine industry has been criticised for its low level of supply chain maturity overall, with various studies suggesting a focus on benchmarking and best practice research in this industry (Chandes and Estampe, 2003; Blok *et al.*, 2013, Donati, 2013; van Eeden *et al.*, 2014). Even Estampe *et al.'s* (2013) review of various supply chain benchmarking techniques has been partly based on their studies on the wine supply chain. Yet what are the supply chain practices in this industry? These are the questions this study aims to answer. The aim of this paper is, therefore, to explore practices in the wine supply chain, and to thereby evaluate a framework of supply chain practices through a multiple case study. The study at hand compares a multi-national corporation (MNC) in the wine industry with insights from several local small winemakers in Australia. The study applies the supply chain practice framework that Spens *et al.* (2014) had developed for the wine supply chain on these cases, and evaluates the framework through them. Conclusions are presented for supply chain practice literature, as well as for the wine supply chain.

2. WINE SUPPLY CHAINS

Wine supply chains are in essence agro-food supply chains. Their upstream activities and members are limited to aspects of the growth and the packaging of wine (bottling, barrels, other packages), as the wine industry themselves produces the raw materials that is distributed downstream. This is an important limitation to the potential of applying supply chain practices such as flexibility, or outsourcing manufacturing activities – though if taking the perspective of winemakers and wine merchants, growth, production and even packaging and labelling can be outsourced, and also postponement strategies can be applied for packaging, labelling, as

well as the use of (base) wine for other wine-related products such as brandy or sparkling wine. The actor structure of the wine supply chain can thus vary from producer cellars that grow, produce and distribute their wine, to including specific wine makers, merchants, distributors, specialised logistics service providers, wholesalers and retailers (Chandes and Estampe, 2003; Costa-Font *et al.*, 2009; Wilson & Goddard, 2004), to the supply chain of bulk wine that is to be blended (and bottled) elsewhere, to the supply chain of further refined goods. A further level of actors is added through certification bodies, information and training schools (Wilson and Goddard, 2004), but also marketing bodies for specific cluster of wine (e.g. Wine Australia that manages the wine of origin brand of Australian wines as a cluster).

Wine of origin clusters emphasise the provenance of the wine, its quality, and the role of regional production. Vineyards and wineries in these clusters will use cluster to exchange knowledge and information based on relationships (Aylward, 2004; Morrison and Rabellotti, 2009). A study by Aylward of Australian clusters identified an «innovative cluster» where collaboration and innovation were linked to improved production and where supply chain integration offered competitive advantages on the export market (Aylward, 2004).

In the academic literature wine supply chains are usually studied by type of products or by actors or through a combination of both depending on their research topic and geographical constraints. Spawton (1990) offers a simple dichotomous approach between fine wines with a focus on high margins, specialist outlets, control of scarcity and ageing and beverage wines with a focus on price competition where continuous availability and stock turnover are prioritized. Chandes and Estampe (2003) through their investigation of the logistics performance of actors in the wine supply chain in the Bordeaux region identify four types of products and specific distribution strategies: branded wines, store brands, «Grand Crus» (fine wines) and wines marketed directly by the winemaker to the clients. They highlight the potential for efficiency gains in the branded and store brand categories where information and actors are better integrated (Chandes and Estampe, 2003). The use of integration in supply chains was also put forward as a key success factor by Mora after his investigation of the Bordeaux wine crisis (Mora, 2006). In New Zealand a study by Tipples explores the fragility of the link in wine supply chains with major retailers (Tipples, 2010) while another New Zealand study by Wilson and Goddard (2004) analyse the various inputs of the supply chain and how their relationships create value. In Portugal, Brito (2006) develops a holistic overview of the port wine sector and puts forward a strong emphasis on relationships. The role of relationships is further reprised by Thah and Olsen (2006) as being relevant in creating strategic partnerships in the US winery sector. Both the themes of integration and relationships for wine supply chains are put forward in the literature discussing wine supply chains, this reflects some of the trends found in supply chain practices and is in line with the findings of Beaujanot *et al.* (2004) who in their study of Australian firms identify that a strong market orientation and a long-term relationship orientation leads to better firm performance.

A customer focus also plays an important role in the context of wine supply chains. Supply chains that have a strong market orientation obtain better firm performance (Beaujanot *et al.*, 2004). Indeed, one of the key success factors in wine industry is to move as close as possible to the market (Mora, 2006). Market orientation was also linked to success in exports in the Australian wine industry (Jordan *et al.*, 2007).

Energy efficiency is also another topic of interest in the context of greenhouse gas emissions and international wine associations and country federations have developed protocols and accounting tools for greenhouse gas emissions (OIV, 2011; FIVS, 2008; WFA, 2012). Emissions in the wine supply chains are mostly produced by packaging/bottling and distribution (Bosco *et al.*, 2011; Neto *et al.*, 2013; Reich-Weiser *et al.*, 2010).

Overall, wine supply chains can be fairly complex with multiple actors or fairly simple with a winery handling every step from grape growing to sales to the consumer. Gurau and Duqesnois (2008) distinguish between wine supply chains that focus on direct distribution, in other words, the sales in wine caves and wineries, markets, trade shows, by mail, via the internet or through associations of producers; and indirect distribution that takes place through channels such as small or specialized shops, supermarkets restaurants and through exports.

3. SUPPLY CHAIN PRACTICES IN THE WINE SUPPLY CHAIN

Logistics and supply chain management has seen various eras (Kent and Flint, 1997, Skjøtt-Larsen, 2000; Spens and Kovács, 2010), thus not surprisingly, supply chain practices are also under constant evolution. Trends in terms of supply chain practices can be depicted both in time, as well as across different geographical areas (Koh *et al.*, 2007; Spens and Wisner, 2009). More recently, Chae (2015) has analysed supply chain-related tweets for trends in their content, indicating the areas of sustainability, and big data to be of rather current concern. Importantly for this study, supply chain practices are also proposed to differ across industries (Kovács and Tatham, 2009; Christopher and Holweg, 2011; Fawcett *et al.*, 2011).

Borgström (2012) has suggested a specific methodology for studying supply chain practice, which she calls the "mystery methodology" that in essence uses an abductive research approach. She postulates that the focus of supply chain practice research is something that is potentially interesting and that cannot be solved or explained by extant literature.

Given the suggested low supply chain maturity of the wine industry, supply chain practice in this industry constitutes some level of mystery. Spens *et al.* (2014) have previously collected and structured supply chain practice literature in this industry, distinguishing between best practice and baseline practice. According to them, baseline supply chain practice includes the dimensions of planning and procurement, manufacturing, inventory management, transportation, distribution and warehousing. Decomposing these further, for example, planning and procurement would include practices such as range forecasting, sales and operations, collaborative forecasting and information sharing with suppliers, sourcing information, private models for marketplaces, collaborative planning, supplier development, strategic sourcing, supplier relationship management. Each of the others can be similarly decomposed (see Table 1). More interestingly, their model also lists best practices, which are proposed to include customer orientation, process integration, supply chain visibility, strategic supplier partnerships, a higher level of information sharing with high information quality, and supply chain collaboration.

Overall, two observations stand out; firstly, a functional view dominates baseline practices, as in Mangan and Christopher's (2005) model of logistics skills, whereas best practices refer to more relational skills that extend to the supply chain. Secondly, Spens *et al.* (2014) detected some differences in the importance of various best practices in the wine supply chain, with the top three being customer orientation, process integration, and visibility. However, Spens *et al.* (2014) could not find evidence in wine supply chain literature for the practices of customer orientation, process integration, nor visibility, in spite of these being the typical "top three" best practices in supply chain management literature overall. This study thus sets out to investigate the mystery of the lack of the presence of these practices in wine supply chains. The ultimate driver for investigating supply chain practices is that they are suggested to have a positive effect both on firm and supply chain performance (Spens and Wisner, 2009; Prajogo and Olhager, 2012).

Table 1: Best practices vs. baseline practices (adapted from Spens *et al.*, 2014)

Best practice	**Baseline practice**
Customer orientation: helps ensure the integration of key business processes in order to respond accurately and in a timely way to customer requests.	*Planning and Procurement.* Range forecasting, sales and operations, collaborative forecasting, planning and information sharing, sourcing information, private models for marketplaces, supplier development, strategic sourcing, supplier relationship management.
Process integration is imperative for the alignment of a company's operational and supply chain strategy with other functional areas, as well as with those of suppliers and customers.	*Manufacturing.* Lean manufacturing, demand-driven networks, six sigma quality control approaches, supply-chain operations reference models, product life cycle analysis.
Visibility is a prerequisite to agility and responsiveness and the key to visibility is shared information.	*Inventory management.* VMI, Postponement, collaborative forecasting, ABC classification, cross-docking, echelon inventory systems
Strategic supplier partnerships. Sourcing decisions are fundamental and the choice of supplier and associated question of how businesses are effectively integrated to maximize their complementary skills are important issues.	*Transportation.* Collaborative relationships, multimodal transport systems, transportation management systems (TMS), carrier cooperation, transport planning, transport network reconfiguration, customer centric transportation processes
Level of information sharing: refers to the extent to which non-public information is communicated along the supply chain.	*Distribution and warehousing.* Outsourcing, warehouse management systems (WMS), customer relationship management (CRM), customer lifetime value, parts management
Information quality: refers to the accuracy, credibility and timeliness of information shared between trading partners.	
Integration intensity. Integration intensity reflects the links that allow to improve information processing between functional departments, as well as externally between trading partners	
Collaboration. Internal collaboration is imperative for effective integration and alignment of a company's operation. Externally, collaboration fosters and stimulates information sharing.	

But while Spens *et al.'s* (2014) framework is a pyramid of best vs. baseline practices, as they have also not found evidence to support this as a type of ranking in the wine supply chain in particular, we will now proceed with evaluating their framework and the practices listed in them through our case studies.

4. METHODOLOGY

Due to this being supply chain practice research, we follow Borgström's (2012) mystery methodology. As she suggests, mystery methodology follows an abductive process. In this regard, our puzzling point was constituted of the results in the Spens *et al.* (2014) study that the top best practices in supply chain practice literature were not echoed in wine supply chain literature. In supply chain management, mystery methodology can either set out to study a particular supply chain, or a particular social practices (Borgström, 2012). Importantly, the methodology focuses on the context specificity of knowledge, or practices – which we here apply to the wine supply chain. However, we deviate from the mystery methodology in that we study a list of practices, both on baseline and best practice levels (see Diaz *et al.*, 2011) instead of being only steered by data. The resultant empirical study is a multiple case study in which we compare the views of a multi-national corporation (MNC) in the wine industry with insights from several local small winemakers in Australia. This follows purposeful sampling

to enable such a comparison, as the two types of winemakers and their difference in scale bring about different supply chain considerations and practices. In both cases, snowballing was used to identify further respondents. Even though snowballing was used inside an organisation, the different organisation were contacted separately which helps to have independent cases.

A semi-structured interview guide has been developed for data collection. This interview guide follows the Spens *et al.* (2014) framework on supply chain practice, and complements it with questions on strategy and key performance indicators, as well as on issues related to climate change. The interviews started with an explanation of the study and of the Spens *et al.* (2014) framework. The first set of questions asked for a description of the supply chain and its development from a historical perspective. A second group of questions asked about the supply chain strategy of the company, and in light of this strategy, the performance measures that were perceived as key. But whilst performance was central in the interview guide, more specific data on actual key performance indicators (KPI) was not collected. Rather, the section on performance was added due to supply chain practice literature emphasising the link between practice and performance (Fawcett *et al.*, 2011; Estampe *et al.*, 2013; Golicic and Smith, 2013). Next, we asked about the practices in the supply chain, particularly asking the question of what respondents perceived they were "best" at. Thus, the interpretation of "best practice" was left to respondents, revealing their views on what constitutes best in their context. Last but not least, a group of questions was added to uncover how these supply chains dealt with disruptions, and with climate change. The section on climate change followed was added due to the impacts of climate change on viticulture overall, but also due to aspects of it in relation to the cold chain (Ting *et al.*, 2014).

The data collected for this research consists of interview notes, field visit notes and transcripts of interviews. Interviews for the large multinational company were done in its home country (Spain) as well as in another country where it owns two major winery estates (Australia). This large multinational company produces hundreds of thousands of bottle of wine every year at these locations and exports its products across the world under different brands linked to their country of origin. Furthermore, the Australian operations are also responsible to manage Spanish importations as well as market development for all brands of the organization across South East Asia. While, the small cluster of wineries is located near Caboolture north of Brisbane in Australia. Interviews were done with three different wineries, in this case the production capacity varied from 10 thousand to 40 thousand bottles a year. None of the wineries were active in the international market and distributed directly to clients through cellar doors, fairs, mail or internet. A total of 4 organisations were studied, one large multinational in two of its different international operations and three small local wineries. The interviews were recorded and notes were taken, there is 282 minutes of interview with 8 interviewees. The interviewees of the small winery were mostly the owners and operators while the interviewees of the multinational winery were managers in the organization.

Template analysis was used as analysis technique for this study. Template analysis is a method in which a list of themes or codes, organized in a certain way to represent relationships between themes, is used to guide the analysis of textual data (King, 2004; Waring and Wainwright, 2008). The themes or codes could be extracted from literature, or emerge from the text itself, in any stage of data collection (i.e. before, during or after) (King, 2004; Ryan and Bernard, 2000). Irrespective of how the a priori themes or codes have been identified, a typical element of template analysis is the modification and revision of the template as the researcher reads and analyses the text (King, 2004). The practices listed in the Spens *et al.* (2014) framework were used as the themes for this analysis (see Table 1), as well as their differentiation of actors (grape growers, raw material suppliers, wine producers,

filler/packers, freight forwarders, freight operators, importers, finished goods distributor, wholesaler, retailer, final consumer) and process steps (grape production, wine production, packaging processes, distribution, the consumer phase, end of life). Further coding categories emerged from the data itself and enrich the analysis.

To ensure the trustworthiness of the data a snowballing approach was taken when gathering information from interviews where each interviewee was asked to recommend potential other interviewees. This approach offers the possibility to reach data saturation where the data from interviewees starts repeating itself. Template analysis also achieves trustworthiness through pattern matching and easier coding which strengthens the understanding of the underlying logic from the phenomenon (Yin, 2009; Stuart *et al.*, 2002; Bak, 2005). The data from this research also stems from of multiple cases also offers the possibility to contrast and compare data more effectively and improve the trustworthiness of the analysis. The coding itself was done by researchers knowledgeable of supply chain practices; to ensure inter-coder reliability and consistency a transcript was analysed and coded by the three coders and then evaluated and discussed before the rest of the material was coded.

5. DISCUSSION

Due to the varying degrees of complexity of actors but also activities in the wine supply chain, the analysis separates between different phases of wine supply chains: grape production, wine production, packaging processes, distribution, consumer phase and end of life. While the end of life phase remains at the background in the interviews, all the supply chain phases are present in both the case of small wineries and the one with the large multinational one.

5.1 Growing grapes

In the context of grape growing, for small wineries, the production process is centred on the quality of wine that can be achieved from the grapes, while taking into account specific customer requirements. The quantity produced is restricted and the emphasis is on creating an experience that sells out the supply. The product portfolio is adjusted to meet changing customer demand or to adjust to unfavourable weather. Grape growing might also be outsourced in order to obtain specific varieties of grapes or in case of a failed crop. This implies that grape growing can either be done by the small winery itself or by a preferred supplier with which it builds a strong relationship and sometimes both.

Grape growing can also be included in the strategy of small wineries. Indeed, sustainable farming practices can offer a differentiation in the market place both in terms of the product specification as well as to obtain environmental certifications which might attract a specific niche of clientele.

For larger wineries, grape growing can be done either on a large estate managed by the organization or done by small grape suppliers. In the case of small scale suppliers for large production, strategic supply chain partnerships must be built to insure and control appropriate grape quality. Large grape growing operations might also follow sustainable practices as these help in improving yields. Furthermore, large multinational companies have more supply alternatives and combinations available regarding both the origin and type of the grape, as well as the location of production and the process. These practices can hedge against risks in grape growing and production processes, making the larger producer less vulnerable to e.g. bad local grape crops. However, stability of its brand and product portfolio, the scale of operations and the supporting quality processes reduce the short-term flexibility.

It is also important to note that in general grape growing is affected by the location. The soil, yearly temperature and humidity will affect grape production. In certain areas high humidity make the production of large yields with high quality very costly due to the required sprays and hand picking while drier sunnier areas might require less spray and offer consistent grape quality that can be mechanically harvested.

5.2 Making wine

When it comes to wine production, the small wineries live from the “sense of location”: they engage tightly with other actors within the local wine industry and might also buy grapes from the region and, it is their soil and their fruit that they bottle up as an experience for their customers to enjoy. This customer experience supports product differentiation strategies where small wineries go for high quality niche product that are innovative, have specific characteristics or are well adjusted to their local markets. Smaller wine producers in certain regions will collaborate horizontally to share knowledge, outsource certain activities to each other (buying grape, wine making services) and organize activities such as wine tours.

In the case of large wineries, production is complex and hard to plan although their size allows some flexibility. Large wineries might use standard process management tools like ERP systems to organize their planning and procurement. They also might collaborate with each other inside the industry and share information on different practices. Large wineries will usually aim to make high quality wines and as such manage their incoming grapes carefully and control the process to achieve good quality standards. Large wineries also have some leeway because of their size to try new products and branding strategies to increase their portfolio and diversify their wine making activities.

5.3 Packaging

Packaging options for small wineries are limited by their direct sales approach. For large wineries packaging is more flexible and can take place at different points in the supply chain. This flexibility depends on their packaging suppliers and on the requirements of their customers. Indeed, certain packaging processes can follow a postponement strategy that allows adapting to the labelling requirements of the customer. Other customer requirement might be related to the type of glass, with light weight glass being preferred in the case of Australia.

There are though many packaging options, and different resultant configurations in the wine supply chain. The cases here did not include bulk shipments, however, nor packaging in different countries. Yet, temporary packaging includes barrels (e.g. for aging), and there are various packages involved in transportation and distribution, let alone cardboard to glass to PET bottle options for consumer packages.

5.4 Distribution

When it comes to distribution, smaller wineries will use direct retail channels such as cellar doors, fairs, markets, wine shows, online purchases and distribution via mail service to engage their clients. Thus they manage production and retail themselves. They might also collaborate vertically with specific partners that can’t retail their wines in an exclusive manner. In general they have a strong customer orientation and try to differentiate themselves and may rely on others. Their customer orientation can be seen in engaging directly with the client and expanding their client base through both boutique wine catering and tourism experience (with bus tours, degustation, food-wine pairing). To monitor their performance in distribution small wineries will look at basic financial KPIs or KPIs relevant to their activities (number of bus tours a month for example).

As for the large wine producers the distribution is more complex. Even though they might have a small proportion of sales through their cellar doors they will often orient their activities towards much larger customers and either integrate themselves with large retailers, deliver to large wholesalers or export their wine abroad. When it comes to national market distribution, large producers will often use freight forwarders and develop strategic supplier partnerships with them to gain visibility and integrate with them to monitor and troubleshoot shipping. They will also rely on or choose their freight forwarder's performance to support the requirements for the deliveries to their clients and will develop strong relationships directly with the retailer or wholesalers to aim for efficient distribution and warehousing. Large volumes push producers to strive towards standardization and simplifications of lines/SKUs – in labelling, blank stock and packaging materials. KPIs are fairly standard and will depend on the actual strategy, i.e. "best practice" and follows strategy-process-performance alignment. However, when the large producers tend to export they use FOB terms which limits the visibility of shipments towards the customer. Another issue that might limit visibility and integration with customers is the push by large retail groups to use farm gate pricing. It should also be noted that country distribution factors might play a role in how a large producers operates. Performing freight forwarders and good partners for export and import might affect the reliability of certain activities and orient the business processes in distribution.

5.5 Consumption

For small wineries the consumer phase is important as it is part of the customer experience which creates value for the customer. In effect they are both the producer and the retailer. This allows a strong customer orientation where they interact directly with their customers and adapt their product offer to follow their taste and improve the customer's knowledge of their product. They also strive to improve the customer experience beyond only wine purchasing by including other services such as entertainment, cafes, food tasting, weddings, specialized services, special events and otherwise tourism related activities. They create relationships with the clients which help market boutique wine but they also find different ways of attracting clients to their retail points (cellar doors) either through tourism or fairs (wine medals) and aim for a combined market of tourism experience and local wine/food enthusiasts. They will often track a few metrics related to direct customer sales and ancillary tourism activity. Sometimes to attract a higher number of customers they will collaborate either in their customer experience activities and complement themselves either in their wine types.

Large wineries are often not involved in the consumption phase other than through brand management or through paying attention to trends and developments in their markets. From this information they will make forecasts to adapt their production levels and make to stock large volumes. The direct sales volumes are a small proportion of sales for the large multinational wine company. However, not only the grapes, but also the identity of the wine brand, is rooted to the soil and the company might show-case vineyards and wine making to attract consumers.

5.6 Other observed factors affecting wine supply chains

Both the small scale wineries and the multinational wine corporation are vulnerable to disruptions arising from different sources. While the collaborative relationships within the local wine industry and the production processes at the heart of the small wineries can more flexibly absorb incremental risks, such as the ones proposed by the environment, for the large wine producer it is the sourcing and pricing practices arrived at through strategic supplier partnerships that can protect the supply chain from the adverse impacts of disruptions. While

the grape growing and wine production processes of the large multinational wine company are also prone to environmental risks, from the point of view of the supply chain as a whole, the role of unpredicted, man-made disruptions, such as dock strikes, were emphasized in the interviews.

5.7 Practices found in wine supply chains

The "best practices" identified by Spens *et al.* (2014) (customer orientation, process integration, visibility, strategic supplier partnerships, level of information sharing, quality of information and collaboration) could be found in both the case of the small wineries and in the case of the multinational corporation. There was however also some evidence that the some of the practices were not relevant in the cases.

Table 2 summarizes examples of the supporting and contradicting evidence of supply chain practices in the two cases. A general conclusion from the comparison of the cases is that the smaller wineries have relatively short and simple supply chains, in which they perform many activities by themselves or by contracting out activities to partners with which they have close and personal relationships, in order to serve customers on a face-to-face and customer experience basis. Customer orientation, information sharing and collaboration (both horizontally and vertically) were important for the performance of the small wineries.

The large, multinational wine producer on the other hand had a much longer and more complex supply chain with many actors, and for example different distribution models for different countries to which products were exported. The volumes supplied to different markets require a large base of grape suppliers and in order to assure a standard quality, strategic supplier relationships have a greater importance than in the case of small wineries, and also visibility, quality of information and level of information sharing has important roles in the more complex supply chain. However, support for all best practices was found in the analysis in the case of the large wine producer.

Table 2 Supporting and contradicting evidence for different supply chain practices

Best practice	The large multinational wine producer	The group of small wine producers
Customer orientation	Supporting evidence: focus on brand and standard qualities; use of postponement and customized packaging. Contradicting evidence: no demand management, only a focus on forecasting	Supporting evidence: focus on creating a consumer experience.
Process integration	Supporting evidence: implementation of information system throughout regional divisions; integration of processes with large retail chains to reduce non-value added steps.	Contradicting evidence: the supply chain is simple with wine producers perform many activities and functions on their own.
Visibility	Supporting evidence: visibility available with operating freight forwarders; visibility of performance with national retail firms. Contradicting evidence: lack of visibility in exports through the use of FOB incoterms.	Supporting evidence: visibility available through transparency of relationships and mutual support
Strategic supplier partnerships	Supporting evidence: long-term relationships with grape growers, knowledge sharing, and quality control in order to achieve quality standards for different products and product categories	Supporting evidence: Suppliers required palliating to disruptions. Contradicting evidence: suppliers selection based on (short) distance and grape availability
Level of information sharing	Supporting evidence: for large national clients there is a strong level of information sharing to monitor performance.	Supporting evidence: sharing of techniques and knowledge across cluster members
Quality of information	Supporting evidence: for retail firms the high level of performance requires accurate information to troubleshoot issues; key performance indicators on the strategy are kept to follow strategy and performance alignment.	Supporting evidence: information sharing and customer teaching is part of the customer experience; some information relative to financial and marketing activities is tracked
Information integration intensity	Supporting evidence: for internal markets, strong linkages to major buyers to improve efficiency of processes.	Contradicting evidence: through direct sales there is little opportunities to reinforce linkages.
Collaboration	Supporting evidence: vertical collaboration with national retail chains to reduce useless materials handling.	Supporting evidence: Horizontal co-operation and sharing of information and knowledge between wine producers.

6. CONCLUSIONS

According to supply chain practice literature, supply chain practice differs across regions, industries, and time. This multiple case study focuses on the specificities of supply chain practice in the wine supply chain – as opposed to literature on supply chain practice overall – and further contrasts the supply chain practices of an MNC with a group of small winemakers.

Previously, Spens *et al.* (2014) have structured supply chain practices in terms of best practice vs. baseline practice. Their results of not finding certain best practices in wine supply chain literature - customer orientation, process integration, and supply chain visibility - formed the starting point of this study. A first and foremost conclusion of our study is that these best practices as well as environmental management, in fact, are key also in the wine supply chain, but are not discussed in supply chain terms. Rather, for example customer orientation is taken up in the light of trends in preferred taste, in wine tourism, and in a strong marketing focus overall. The mystery of best practice in the wine industry is thus partly, a semantic one. At the same time, the findings from the study corroborate that performance, while highlighted in production and the quality of the product, is less in focus in terms of efficiency and effectiveness in the supply chain. The wine supply chain is very manufacturing and marketing-focused, with distribution supporting these activities.

The results from the study indicate that there is a variety of wine producers, wine supply chains, wine supply strategies and supply chain performance. Also external factors such as climate and market structure could have an impact on performance. The differences in size, supply chain length, volumes and contexts of the two cases made it difficult to make comparison and draw precise conclusions on what constitutes best practices in wine supply chains – the low number of cases included in the study can therefore be seen as a limitation. Overall, however, differences in best practice seem to stem from the strategy of a winemaker, and its inherent choice of key performance indicators, rather than the industry alone. More, and more different practices, may be inherent to various companies and their supply chains in the wine industry. Further research is needed to discover their variety, and more importantly, the underlying factors contributing to this variety.

Divisions of best practice vs. baseline practice need to be adapted to the agro-food supply chain overall, and may differ between agro-food supply chains and e.g. services supply chains, but the division is otherwise rather robust. The focus on strategy and performance supports the idea of performance and practice alignment, though further studies are needed to understand whether it is strategy driving performance and practice, whether it is supply chain practice that translates to performance as e.g. postulated by Estampe *et al.* (2013) and Golicic and Smith (2013), or whether supply chain practice has a mediating effect on performance (Zhu *et al.*, 2012).

The study bears though important implications for supply chain management overall. It highlights the context-dependence of supply chain practices (as in Borgström, 2012), and establishes a link between supply chain strategy – performance – and practice. The alignment of these three could be studied more, not only from the perspective of wine supply chains. What is more, such an alignment is postulated in contingency theory, which has though not been applied much in supply chain management research, but could be helpful in uncovering situational, contingency factors that explain the context-dependence of supply chain practices.

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ASSESSING THE EFFICIENCY AND PRODUCTIVITY OF PASSENGER CAR SALES IN NORWAY

AN APPLICATION OF DATA ENVELOPMENT ANALYSIS AND MALMQUIST PRODUCTIVITY INDICES

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ABSTRACT

Purpose – This study examines the efficiency and productivity of the Norwegian passenger car market. The impact of product variety i.e., the number of different variants of the same brand; on efficiency and productivity is also examined.
Design/methodology/approach –Data Envelopment Analysis (DEA) is used to assess efficiency and its extension to Malmquist Productivity Index (MPI) to assess productivity. To infer the impact of product variety on efficiency and productivity, a truncated regression is used.
Findings –On average, the Norwegian passenger car market has a great potential of improving its efficiency in sales by 40% and 65% under the assumption of variable and constant returns to scale of operation, respectively. The MPI reveals that car brands have progressed tremendously by about 38%. About 62% of the car brands studied showed productivity progress throughout the period studied. Product variety is found to impact efficiency positively and productivity negatively.
Limitation of the study – A limitation of the study is that it wasn't possible to obtain data of all car brands. Had this been possible we would have had a much larger data set thus making our conclusions even more robust.
Managerial implication –The results of this study provide the managers with the potentials for efficiency improvements that they may strive to obtain despite the fact that the whole potential may not be possible to achieve.
Originality/value – To our knowledge, this study is the first to examine the performances of car sales in Norway using a succinct methodological framework.
Keywords – Norwegian passenger car sales, Efficiency, Productivity, Product variety.

1. INTRODUCTION

Over the past two decades, the growth of passenger car market has shown signs of slowing down in several developed countries, and in some, growth has stopped or turned negative (Van Dender and Clever, 2013). In contrast, the Norwegian passenger car market has shown slight growth as compared to the rest of Europe. According to Egil Steinsland, communications manager in Norway Automotive Association, the Norwegian passenger vehicle market has been steadily increasing over the past few years, and expects the market growth to level off somewhat in the coming years (Norwaytoday, 2013). In fact, the International Road Federation[1] reported that the Norwegian passenger car market per 1,000 inhabitants has been experiencing a growth trend in spite of the fact that this growth is at a slower pace.

Even so, the history of the Norwegian car market may indicate that there is considerable potential to improve the performance of this sector. First, the Norwegian tax system for cars is something that deserves some more comments and reflections. Its main problem is the high import tax rates on the passenger cars, which in turn affect the selling price. In the eyes of many, this may contribute as a partial impediment to the market; as anticipated the market may become inefficient as well as unprofitable. Thus, less attractive for many investors (car dealers).

Given car dealers' ambition in becoming more profitable in selling different models of cars, the importance of an efficiently functioning car market may be greater than ever. Yet, no research has been conducted on measuring efficiency and productivity of Norwegian passenger car market. Norway is a country that has extremely rich natural resources such as oil and natural gas, and has experienced strong economic growth ever since the discovery of such resources (Bjørke, 2013), prospects for manufacturing its own cars still remains a mystery.

This paper will therefore analyse the performance of the present Norwegian car market and how performance changes of this market can be observed using DEA approach. This is taken from the dealership perspective as opposed to the manufacturing perspective as is the case with most studies (see for e.g. Karaduman, 2006; Chen, 2011; Alex and Chich-Jen, 2013, among others). In order to gain insight into the Norwegian car market this study will attempt to answer the following questions: are there any potentials for efficiency and productivity improvement in the Norwegian passenger car market, and if so, how can such potentials be realised? Similarly, the impact of product variety i.e., the number of different variants of the same brand; on efficiency and productivity is also examined.

AN OVERVIEW OF NORWEGIAN PASSENGER CAR MARKET

The extent and characteristics of competition in the market affect the choice behaviour among the actors (Yadev, 1995). The Norwegian car market structure can be characterised as Monopolistic competition. This implies that each firm (car dealer) makes independent decisions about price and output, based on its product, its market, and its cost of production. However, a central feature of monopolistic competition is that firms differentiate their products. Differentiation takes place in many forms. For example, differentiation can be in the form of human capital, where a firm creates differences through the skill of its employees and the level of training received. Other form of differentiation can be based on the product physical alternation such as design. By doing so, the firm creates a gap between its product and that of its competitors. This may create the perception that there is no close substitute available on the market that matches the firm's product

[1] The International Road Federation is a non-governmental organization that promotes development and maintenance of roads.

Understanding the Norwegian passenger car market mechanism is substantial as it plays a key role through its impact on the decision-making environment. For the most part, Norwegian passenger car market has been attractive for many car companies for the past few years owing to the fact that number of car brands entering the market is constantly increasing. Yet, the market share is not equally shared among car manufacturers as some have held a dominant position in this market for many years. For example, it has been reported that in 2013 Volkswagen Group[2] has held the leading position in the Norwegian passenger car market for the past eight years (MøllerGruppen, 2013). A possible explanation for this dominant position is that the existence of joint ventures formed by big car manufacturers such as Volkswagen, Audi, and Skoda has allowed them to take advantage of the economy of scope by offering higher variety[3] to many segments in the market.

De facto, the driving forces behind this practice are observable at the car dealership level. Larger car dealers with a strong financial position are often franchised by multiple or single automaker[4], and open many workshops in all parts of the country in order to cater for various segments with different models of cars (MøllerGruppen, 2013).

Because the aforementioned strategy is considered as one of the key elements to survive in the market, car manufacturers/dealers have also made great effort to increase their variety in terms of models so that they can maintain or increase their market share/sales. This is seen clearly in the upward trend of the number of new passenger car registration over the past four years (Norwaytoday, 2013). These high sales in the Norwegian passenger car market are not just justified by the aforesaid reasons, there are also technological, political, and economic factors associated with them. The Norwegian government has put forward various types of incentives available for car manufacturers to stimulate more environmentally friendly technologies or practices in their vehicles, which in turn has also affected the Norwegian car market. These incentives have also re-boosted sales, which was shrinking. For example, in 2009 the Norwegian government established a committee named Transnova, and operated as a trial funding program supporting projects making a fast contribution to the adoption of new and greener technology (Odyssee-mure, 2013). As a result of this, a great technology development is made by the car manufacturers on Electric Vehicles (EVs). As of March 2014, a total of 25,710 electric passenger vehicles have been sold, and this has resulted in Norway being home to the largest per capita electric vehicle market in the world (Grønnbil, 2014).

Other forms of incentives, such as exemption from vehicles taxes (registration tax, value added tax), all public parking fees, among others, are also considered as one of the reasons to increase sales. Indeed, these incentives have flourished the Norwegian passenger car market as more models of electric vehicles from different car brands are expected to incline for the coming years.

2. METHODOLOGY

This section briefly describes the analytical techniques used for estimating the relative efficiency and the changes in productivity over periods of time of Norwegian passenger car market. Thus, the analysis is divided into two stages as regards DEA; in the first-stage the efficiencies of Norwegian passenger car market along with the Malmquist Productivity Index

[2] Volkswagen Group is an automotive alliance consists of Volkswagen, Audi, Skoda, and among others
[3] Volkswagen Group offered in 2013 35 car models in the Norwegian passenger car market
[4] Franchised car dealers are recognized by the automaker and follow that company's operational policies

(MPI) are calculated. This paper will however measure only one form of technical efficiency, output-oriented efficiency. This is due to the fact that the main objective of Norwegian passenger car market is to maximise total sales of car models being sold while keeping the level of inputs constant.
The second stage accounts for exogenous variables that are regressed on the derived efficiency/productivity scores. Determining how these variables impact on efficiency is essential for the car market to identify viable performance improvement strategies. The justification for using parametric technique (regression analysis) in this stage of DEA analysis owes its explanation on DEA's inability in summarising the impact of efficiency/productivity of exogenous factors in single coefficient (Odeck, 2009).

1.1. The DEA efficiency measure

DEA has been applied in this study to estimate the output-oriented technical efficiency of individual car brands with different models in Norwegian passenger car market. DEA is based on Farrell's (1957) work, which was later extended by Charnes et al., (1981) and Färe et al., (1985). DEA, as described by (Ganley and Cubbin, 1992), is a non-parametric technique used for measuring relative efficiency of Decision making Units (DMUs).

Thus, DEA establishes the 'best practice' frontier from the given set of inputs and outputs. In this instance, the best practice frontier refers to those units that produce more output with the given level of inputs. Hence, these units act as the benchmark in estimating the performance of other units. As a result, units that are referred to as frontier or benchmark units will be 100 per cent efficient with the efficiency score of one. All other units will have the efficiency score of less than one if they are not on the frontier as this indicates inefficiency. The efficiency of every non-frontier unit[5] is measured in relation to the most efficient unit. One minus the efficiency score of non-frontier units give the percentage by which these units need to increase their outputs in order to be on the best production possibility frontier (PPF).

1.2. The Malmquist Productivity Index (MPI)

This study measures the output efficiency of Norwegian passenger car market between the periods of time (2008 to 2012). In order to accurately estimate the changes in productivity of Norwegian car market between the periods of time, the Malmquist productivity index (Henceforth MPI) is used. As Chen (2011) puts it, the DEA-based Malmquist productivity index has proven to be the most appropriate tool to use for measuring productivity change in various industries.

As far as this study is concerned, the implication of productivity growth for an individual car brand i, based on time series, can be measured by the MPI as improved efficiency relative to the best performers[6]. Thus, MPI is expressed by the two adjacent DEA efficiency measures. In this study's setting, we will estimate productivity of car brands from one time period to the other. Subsequently, these may induce three possibilities as regards productivity; $M_t^i < 1$ indicates a decline in productivity, $M_t^i = 1$ implies no change in productivity from time t to $t+1$ and $M_t^i > 1$ indicates an increase or improvement in productivity.

[5] Non-frontier unit refers to the unit, which is not situated on the production possibility frontier (PPF).
[6] Also known as the benchmark frontier

The Malmquist index according to Färe et al., (1992), is decomposed into two mutually exclusive and exhaustive components that may help in explicating efficiency and inefficiency reasons. Thus, the efficiency change component *(TEC^i)*, also known as the 'catching up', is an index of relative technical efficiency change between periods for car brand *i*. On the flip side, the technical change component[7](FS^i) indicates the relative distance between the frontiers.

3. THE DATA

Following Odeck (2008), in order to be able to measure the technical efficiency of Norwegian passenger car market profoundly using the DEA technique described above, the following requirements are considered, that: 1) The data set includes clearly the identified production units (car brands). 2) The identified output for each car brand indicates the services produced. 3) The inputs for each brand indicate the resources that are used to produce those services. 4) The individual car brands being evaluated are comparable in the sense that they utilise the same types of inputs to produce the same types of services. All the car dealerships of the selected car brands in this study are similar in the sense that they only deal with a single brand and not a mixture of brands.

Car dealerships' data is the backbone of the analysis in this study given that not a single car is manufactured in Norway. Due to the high level of complexity and scope that exists in the Norwegian passenger car market, it is not possible to include all brands in the analysis. For the sake of simplification, the sample size is restrained apropos car brands, and used mixture techniques in the data collection. Naturally, this will enable us to assess whether the sample drawn in the analysis is large enough to represent the population, and provide unbiased results.

In this study, all the data used are from 2008 to 2012. This five-year period is chosen as it is the period with complete and most reliable data for all the selected car brands. However, understanding the business practice of these car dealers with their subsidiaries is one of the main obstacles when collecting data, as such a prerequisite is established. One of the main criteria used is to select dealers that are franchised by brands, and operate for a single brand. By doing so, double counting in the data is avoided and this will enable us to make a fair assessment between brands.

In pursuance of the criterion adopted, 34 bestselling car brands in Norway are selected based on the ranking released by Opplysningsrådet for Veitrafikken AS (OFV) according to quarter one of 2014. Following the brands selection, several sources are consulted in order to collect financial information about car dealers, and crosscheck the data. Based on the aforementioned criteria, only 21 brands qualified for the sample test, and the remaining brands are removed because of the following reasons: 1) They do not meet our criteria of having one car dealership exclusively operating under their brand name. For the most part franchised car dealers operate under multiple car brands. 2) Few car dealers (e.g. Tesla) does not have sufficient information for all years of observation (2008-2012) or in some cases financial reports are not made readily available to the general public. 3) The financial reports for some brands, in particular Mazda and SsangYong contain significant costs fluctuation in several years of observation, which might negatively influence the results. After having decided which brands to include in the sample, the following approach is used for collecting the financial information about dealers of the selected brands. First, the obtained financial data[8] about the dealers are adjusted according

[7] Also known as 'frontier productivity index' or 'frontier shift'.

[8] Financial information in this study , which is used as inputs for our analysis, refers to as labour cost, capital cost, depreciation and other expenses

to the consumer price index (CPI) as fluctuating prices distort the economy's price signals, and can result in the misinterpretation of results. However, it should be noted that for calculating the CPI the year 1998 is used as the base year.

This implies that the study consists of about 62% of the total bestselling brands in Norway. This number is more than sufficient to give conclusion or information on how these car brands perform in general. Nevertheless, since this number represents only part of the total bestselling brands, it is important to take caution regarding the conclusion drawn from this. An extra care in interpreting these results is therefore advised.

The efficiency and productivity assessment requires that inputs and output(s) be identified. This study has four inputs and one output making a total of five items. This matches with the DMU's rule of thumb where the number of DMUs (car brands represented by n) is equal to or greater than max $[m \times s, 3 \times (m + s)]$. Where, m and s denote inputs and output, respectively. Thus, we have 21 car brands as our DMUs and that means the DEA convention that the minimum number of DMUs should be greater than 3 times the number of inputs plus outputs $\{21 > 3\ (4 + 1\ )\}$has been maintained in this study. According to Asmild et al., (2004), if this rule of thumb is not met, the DEA results will be biased and questionable. Put simply, the model may produce a large portion of the DMUs that will be identified as efficient and decrease discriminating power, hence giving misleading results. Hence, from the available data, one output is specified: the total number of vehicles imported multiplied by the selling price of car brand. This is the significant cost driver for car dealerships in Norway.

The inputs required to handle number of imported vehicles and to make sure such vehicles are sold include labour costs, capital costs, depreciation and other expenses. Labour cost includes direct wage payments of sales people. Capital cost includes the total fixed assets, which imply expenses incurred by the previously mentioned car dealerships on the purchase of property, plant and equipment used in the rendering of services[9]. Nevertheless, depreciation in this study is measured by the amount of depreciation indicated in the financial report of the selected car brands' dealerships. Lastly but not least are other expenses which include insurance, office supplies, utilities, legal fees, among others.

The main analyses are thus based on one output (total sales of cars imported) and four inputs (labour and capital costs, depreciation and other expenses). In addition to these variables, there are other 'exogenous' variables which can impact the performance of the car dealerships even though they cannot be controlled by them. The first is product variety, which in this case is measured by number of car models, fuel type, chassis type, horsepower and engine displacement. Thus, it might be argued that those car brands with low variety in terms of the aforesaid measures will have an advantage in light of efficiency as compared to those with high product variety. It is claimed that high product variety as far as importation of cars is concerned, implies higher costs due to the market's expensive import tax imposed on these cars. This therefore entails an inability to realise economies of scale. Second, firm size that is measured by number of dealers. The bigger the firm/car dealership the more efficient it is due to economies of scale. Finally, age of car brand (how long the brand has been in the market) is the third one. It is assumed that the older the company, the more efficient it is relative to the younger ones.

[9] This implies selling of different models of cars as this requires land, buildings, and machinery/equipment.

4. EMPIRICAL RESULTS

In this section, the efficiency results are presented first, followed by the productivity growth of the Norwegian passenger car market and finally but not least, the truncated regression analysis.

5.1 Relative efficiency of Norwegian passenger car market

Table 5.1 reports the results for the first-stage output increasing DEA efficiency scores for all the car brands; under the assumption of both variable return to scale (VRS) and constant return to scale (CRS)[10]. The results are reported on an annual basis with observation and a summary statistic representing averages, standard deviation and, maximum and minimum values for all the years of observation (2008-2012). This approach of analysing performance of Norwegian car market year by year is applied in this study simply because we are interested in knowing how the change in the performance of such a market has been from one year to the next based on the prevalent frontier for each year.

Under the assumption of VRS, Table 5.1 shows that the average efficiency score across sample years is about 0.60. This result reveals that there is indeed a presence of inefficiency in the car market. This implies that on average car brands can improve their efficiency or reduce their inefficiencies proportionately, by augmenting their outputs by approximately 40% without altering the inputs levels.

By looking at standard deviation score of 30 – 36% from Table 5.1, one can observe that there is a great variation in the performance of brands in the Norwegian car market. There are some brands that operate either on or close to the frontier, but still, about 81% of the brands exhibit inefficiencies. These may be explained due to misallocation of resources that have been linked to higher costs in selling different models of passenger cars (high product variety) leading to inefficiency. In other words, the monetary rate of return from firms differentiating their product is insignificant.

Further analysis on the individual car brands as shown in Table 5.1 reveals some interesting patterns that can be observed in this market. First of all, the descriptive statistics shown at the lower part of the table indicates that there has been extreme variation among brands given that the best performance car brands score 100% in efficiency, whereas poorest performance is approximately 12%. For example, the result in Table 5.1 under VRS assumption reveals that across all years of observation there are only four brands; CB1 (Volkswagen), CB10 (Mercedes-Benz), CB15 (Suzuki) and CB20 (Chevrolet) that achieve best performance (efficiency score of 1), and this roughly represents 19% of the sample being studied. The inefficiency under the VRS assumption in the Norwegian passenger car market may be justified by the incompetent of the market to reach the optimal quantity.

Conversely, it is observed that there is little variation in efficiency scores for individual car brands across the sample years. This applies to those brands that are 100% efficient in one or more years but not in all the years of observation even though their efficiency performances seem not far from those with the best performance. Such brands include among others, CB3 (BMW), which has been 100% efficient in all the sample years except for 2009, even though the variation is very little. Actually, about 76% of the car brands experienced inefficiencies in 2009. The global crisis may be the main cause and may have significantly affected the car market as the total sales in that year shrank for the most brands by 12%. In addition to this, the political pressure on car brands, where the Norwegian government introduced monetary incentives, to develop their technology on electric cars may be considered as one of the reasons.

[10] We obtain CRS by multiplying the variable return to scale (VRS) scores with the scale efficiency index (SE).

Based on these grounds, many brands have paid a high price for it. For example, in 2009 Mitsubishi reported that their global sales decreased due to economic crunch, and also expressed their interest in developing electric cars (Mitsubishi-motors, 2009).

Table 5.1: Efficiency results for Norwegian passenger car market

DMU No.	DMU Name	Output-Oriented VRS						Output-Oriented CRS					
		2008	2009	2010	2011	2012	Average	2008	2009	2010	2011	2012	Average
CB1	Volkswagen	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	0,21	0,17	0,24	0,25	0,21	0,22
CB2	Toyota	0,70	0,79	0,63	0,53	0,66	0,66	0,07	0,08	0,09	0,08	0,09	0,08
CB3	BMW	**1,00**	0,90	**1,00**	**1,00**	**1,00**	0,98	0,81	0,71	**1,00**	**1,00**	**1,00**	0,90
CB4	Nissan	0,43	0,36	0,42	0,42	0,46	0,42	0,20	0,16	0,20	0,21	0,21	0,20
CB5	Volvo	0,68	0,98	**1,00**	**1,00**	0,93	0,92	0,19	0,33	0,36	0,40	0,27	0,31
CB6	Ford	0,62	0,68	0,65	0,69	0,62	0,65	0,17	0,15	0,17	0,22	0,17	0,17
CB7	Audi	**1,00**	0,85	0,83	**1,00**	0,96	0,93	0,44	0,31	0,30	0,36	0,33	0,35
CB8	Mitsubishi	0,58	0,32	0,35	0,67	0,38	0,46	0,58	0,32	0,31	0,66	0,36	0,44
CB9	Skoda	0,27	0,33	0,40	0,46	0,35	0,36	0,10	0,10	0,13	0,17	0,13	0,12
CB10	Mercedes-Benz	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**
CB11	Peugeot	0,47	0,40	0,62	0,64	0,49	0,52	0,34	0,31	0,52	0,49	0,38	0,41
CB12	Opel	0,32	0,35	0,29	0,33	0,24	0,31	0,17	0,22	0,18	0,28	0,19	0,21
CB13	Kia	0,20	0,10	0,18	0,27	0,35	0,22	0,15	0,10	0,18	0,26	0,35	0,21
CB14	Citroen	0,17	0,14	0,19	0,27	0,26	0,21	0,13	0,10	0,14	0,25	0,26	0,17
CB15	Suzuki	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	0,64	**1,00**	**1,00**	0,68	0,86
CB16	Subaru	0,33	0,27	0,31	0,25	0,36	0,30	0,22	0,23	0,27	0,20	0,34	0,25
CB17	Honda	**1,00**	**1,00**	0,76	0,65	0,77	0,84	**1,00**	0,74	0,67	0,59	0,53	0,70
CB18	Hyundai	0,10	0,21	0,33	0,50	0,39	0,31	0,05	0,12	0,19	0,29	0,24	0,18
CB19	Land Rover	0,11	0,12	**1,00**	0,30	0,44	0,39	0,09	0,09	0,37	0,11	0,27	0,19
CB20	Chevrolet	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	0,36	0,31	0,02	0,01	0,08	0,16
CB21	Porsche	0,04	0,09	0,13	0,12	0,23	0,12	0,03	0,07	0,13	0,12	0,22	0,11
	Average	**0,57**	**0,57**	**0,62**	**0,62**	**0,61**	**0,60**	**0,35**	**0,30**	**0,36**	**0,38**	**0,35**	**0,35**
	Max	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**
	Min	**0,04**	**0,09**	**0,13**	**0,12**	**0,23**	**0,12**	**0,03**	**0,07**	**0,02**	**0,01**	**0,08**	**0,08**
	S.D.	**0,36**	**0,36**	**0,33**	**0,31**	**0,30**	**0,32**	**0,33**	**0,26**	**0,31**	**0,30**	**0,26**	**0,28**

Moreover, CB19 (Land Rover) experiences extreme unbalance in their efficiency performances with great variations. In 2010, Land Rover is seen to be most efficient and has been since showing a worst condition as it has the lowest potential for improvement. This may be due to the merge of Tata Group and Land Rover that resulted in changing operational activities of these firms. For instance, there has been consistent increase in its sales since the launch of the 2010 model year range, which boasts the latest, most efficient and technologically advanced line-up for Land Rover in its history (NewsroomLandRover, 2010).

However, one should bear in mind that brands that are efficient with a performance score of 1.00 are relatively efficient and not strictly efficient. This implies that no other brand is clearly operating more efficiently than these car brands, but it is possible that all units, including these relatively efficient brands, can be operated more efficiently.

The right-hand side of Table 5.1 presents efficiency scores under the assumption of CRS. The average efficiency score across all the years of observation is 0.35. This entails that the average potential for increasing output among the dealers in Norwegian car market is about 65%. Despite being the same sector, CRS average inefficiency scores are higher as compared to VRS scores. In terms of standard deviation, this sector under CRS assumption shows that there is great variation in efficiency scores between the car dealerships (standard deviation of 26-31%). Hence, showing an extreme situation where some dealerships are 100% efficient whereas others are as low as 8%, meaning they are not efficient at all. This higher mean and lower standard deviation scores in CRS results confirm the poor performance of the sector on selling numerous different models of cars (high product variety). Thus, larger car brands are just as inefficient as

small ones in converting inputs to output. Comparing CRS efficiency scores of individual dealerships to that of VRS, it is observed that CRS reveals that only one dealership (Mercedes-Benz) is the most efficient in all the years of observation. The remaining car brands are most efficient but not in all the sample years of observation. Mercedes-Benz in this case can be used as a benchmark for measuring efficiency with the other car brands.

Next, considering the scale of efficiency measure (SE_i)[11], which indicates the degree to which the car dealers are optimising the size of their operations. This measure is obtained by computing the ratio (CRS/VRS), and the results are set out in Table 5.2. The average scale of efficiency of the twenty-one car brands is 62%, implying that the average size of brands is less than 50% from the optimal size, and further increase optimal scale of 38%[12] would be feasible assuming there is no other constraining factors provided they adjust their car workshops operation to an optimal scale. The average level of overall standard deviation, minimum and maximum is estimated at 0.29, 0.13, and 1.00 respectively. Given that the standard deviation is smaller than the average, there is an apparent indication of moderate variability among car brands.

The results presented in Table 5.2 therefore show that Mercedes-Benz is the only brand that is using its scale efficiently over all years of observation, which can be due to constant return to scale. Further, we can note that brands such as BMW and Suzuki show presence of scale efficiency but with anomalies in their scores over the years though the variation is little and both operate with constant return to scale just like Benz. This excellent performance of Mercedes Benz may be justified by various reasons. Thus, the key lies in Mercedes Benz constantly minimizing the inputs cost (on average approximately 2.66% of the total sales) and operates at optimal level of scale efficiency, these points are considered as the key success factors in being efficient in the market.

However, Toyota is considered the one with the poorest performance (87% scale inefficient) relative to the other brands. This may be explained in terms of safety-related recalls that are considered the red-hot-button in the car business nowadays. For example, in 2009 Toyota recalled -1.8 million vehicles sold in Europe due to faulty braking, sticky gas pedal and defective floor mats (CBS News, 2010). This may have added additional costs to the company hence scale inefficient[13]. Nonetheless, the result reveals that about half of the scale-inefficient brands (14 brands or 67%) are operating under decreasing returns to scale, which entails that a given proportional change in inputs utilised by such brands results in a proportional smaller change in their output.

[11] A score of 1 indicates scale efficiency whereas a score of less than 1 indicates otherwise (scale inefficiency).

[12] This also implies that the sector has about 38% potential for efficiency gains in light of scale.

[13] This is devastating for Toyota especially considering that in the 1990s they used to be efficient and progressed well in productivity due to introduction of Toyota Production System (TPS) that eliminated the negative consequences of increased product variety on the company's performance (Monden, 1994).

Table 5.2: Scale of Efficiency (SE) and Scale of operation

DMU No.	DMU Name	SE						Scale of operation-sum of weights (SW)					Returns to scale
		2008	2009	2010	2011	2012	Average	2008	2009	2010	2011	2012	
CB1	Volkswagen	0,21	0,17	0,24	0,25	0,21	0,22	40,58	8,53	10,00	9,85	9,29	Decreasing
CB2	Toyota	0,11	0,10	0,15	0,15	0,14	0,13	79,10	14,28	43,90	37,93	14,28	Decreasing
CB3	BMW	0,81	0,78	**1,00**	**1,00**	**1,00**	0,92	6,54	1,29	1,00	1,00	1,00	Constant
CB4	Nissan	0,47	0,46	0,48	0,50	0,46	0,47	9,75	2,35	2,85	5,97	2,49	Decreasing
CB5	Volvo	0,28	0,33	0,36	0,40	0,28	0,33	24,30	3,36	4,33	6,84	5,26	Decreasing
CB6	Ford	0,27	0,22	0,26	0,31	0,27	0,27	24,15	5,94	6,48	5,64	5,68	Decreasing
CB7	Audi	0,44	0,37	0,37	0,36	0,35	0,38	12,84	3,09	5,81	4,14	3,61	Decreasing
CB8	Mitsubishi	0,99	0,99	0,88	0,99	0,96	0,96	3,24	0,80	1,26	0,96	0,87	Increasing
CB9	Skoda	0,35	0,32	0,31	0,37	0,36	0,34	16,96	3,74	4,73	4,03	3,63	Decreasing
CB10	Mercedes-Benz	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	1,00	1,00	1,00	1,00	1,00	Constant
CB11	Peugeot	0,71	0,78	0,85	0,77	0,78	0,78	3,96	1,31	1,22	5,93	1,32	Decreasing
CB12	Opel	0,53	0,62	0,62	0,84	0,80	0,68	9,14	1,70	2,20	1,32	1,42	Decreasing
CB13	Kia	0,76	0,95	0,98	0,97	0,99	0,93	3,27	0,64	1,75	1,72	0,93	Decreasing
CB14	Citroen	0,75	0,70	0,73	0,95	0,97	0,82	5,82	1,48	1,61	0,77	0,88	Decreasing
CB15	Suzuki	**1,00**	0,64	**1,00**	**1,00**	0,68	0,86	1,00	0,20	1,00	1,00	0,19	Constant
CB16	Subaru	0,66	0,85	0,85	0,81	0,95	0,82	6,05	1,18	5,53	5,92	1,07	Decreasing
CB17	Honda	**1,00**	0,74	0,89	0,91	0,69	0,84	1,00	0,33	0,30	0,92	0,32	Increasing
CB18	Hyundai	0,52	0,55	0,59	0,58	0,61	0,57	10,58	1,90	5,38	8,85	1,78	Decreasing
CB19	Land Rover	0,82	0,72	0,37	0,37	0,61	0,58	2,03	0,33	0,04	0,36	0,39	Increasing
CB20	Chevrolet	0,36	0,31	0,02	0,01	0,08	0,16	0,25	0,07	0,21	0,36	0,18	Increasing
CB21	Porsche	0,89	0,82	0,95	0,96	0,93	0,91	2,05	0,33	1,84	1,62	0,52	Decreasing
	Average	**0,61**	**0,59**	**0,61**	**0,64**	**0,63**	**0,62**	**12,55**	**2,56**	**4,88**	**5,05**	**2,67**	
	Max	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**79,10**	**14,28**	**43,90**	**37,93**	**14,28**	
	Min	**0,11**	**0,10**	**0,02**	**0,01**	**0,08**	**0,13**	**0,25**	**0,07**	**0,04**	**0,36**	**0,18**	
	S.D.	**0,29**	**0,28**	**0,32**	**0,33**	**0,32**	**0,29**	**18,27**	**3,39**	**9,31**	**8,09**	**3,50**	

5.2 Productivity Growth in the Norwegian car market

MPI is used in this study in order to investigate how the efficiency of Norwegian passenger car market has changed over time using the moving base year technique14 where productivity is measured with the previous year as a base year. This will show us the change in productivity from one year to the next. Furthermore, it will show which components of productivity leads to regress or progress as discussed earlier. The empirical results of the MPI and its successive components are shown in Table 5.3.

An interpretation of the indexes i.e. Malmquist index (MPI), technical efficiency change (TEC^i), and frontier shift index (FS^i) reported in Table 5.3 should be emphasised with regards to their sizes. It is possible to have an index value that is greater than one, e.g. $M_t^i > 1$, implying that efficiency in period *t+1* is greater relative to that of the previous year (period *t*). In contrast, an index value of one ($M_t^i = 1$) and less than one ($M_t^i < 1$) indicate productivity stagnant and decline, respectively. This is not controversial at all with regards the efficiency performance score as discussed earlier; if greater than 1, it only means that efficiency in the succeeding year is greater than the preceding year.

[14] The first four periods are analysed using a moving base year technique, except for the fifth period (2008-2012) where 2008 is the only base year.

Table 5.3: Productivity growth measured by the Malmquist productivity index (MPI) and its components

No.	DMU Name	2008-2009			2009-2010			2010-2011			2011-2012			2008-2012		
		MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS	MPI	TEC	FS
CB1	Volkswagen	0,92	0,85	1,08	1,49	1,40	1,07	0,88	1,03	0,86	0,89	0,84	1,06	1,03	1,02	1,01
CB2	Toyota	0,88	1,12	0,79	1,08	1,13	0,96	0,77	0,87	0,88	1,17	1,11	1,06	0,88	1,23	0,72
CB3	BMW	1,07	0,88	1,22	1,43	1,41	1,02	1,06	1,00	1,06	0,93	1,00	0,93	1,36	1,24	1,10
CB4	Nissan	0,74	0,82	0,91	1,11	1,21	0,92	0,90	1,04	0,86	1,19	1,02	1,17	0,89	1,06	0,84
CB5	Volvo	1,75	1,73	1,01	0,91	1,08	0,84	0,94	1,12	0,84	0,76	0,66	1,14	1,44	1,40	1,03
CB6	Ford	0,95	0,88	1,08	1,35	1,17	1,16	1,04	1,26	0,83	0,79	0,78	1,01	1,05	1,01	1,05
CB7	Audi	0,77	0,71	1,08	0,99	0,98	1,01	1,00	1,18	0,85	0,97	0,93	1,05	0,79	0,76	1,04
CB8	Mitsubishi	0,59	0,55	1,08	1,11	0,97	1,15	1,81	2,17	0,84	0,56	0,55	1,02	0,67	0,63	1,06
CB9	Skoda	1,17	1,09	1,08	1,42	1,22	1,16	1,09	1,33	0,82	0,76	0,75	1,01	1,38	1,32	1,04
CB10	Mercedes-Benz	1,24	1,00	1,24	0,99	1,00	0,99	0,81	1,00	0,81	1,13	1,00	1,13	1,16	1,00	1,16
CB11	Peugeot	0,85	0,93	0,92	1,42	1,68	0,84	0,87	0,94	0,93	0,85	0,78	1,09	0,89	1,14	0,78
CB12	Opel	1,37	1,30	1,06	0,94	0,85	1,11	1,30	1,53	0,85	0,71	0,69	1,02	1,15	1,16	0,99
CB13	Kia	0,54	0,65	0,83	1,68	1,79	0,94	1,30	1,48	0,88	1,43	1,33	1,08	1,82	2,28	0,80
CB14	Citroen	0,84	0,78	1,08	1,62	1,42	1,14	1,55	1,82	0,85	1,03	1,01	1,02	2,15	2,02	1,07
CB15	Suzuki	0,51	0,64	0,79	1,52	1,56	0,98	0,93	1,00	0,93	0,67	0,68	0,99	0,48	0,68	0,70
CB16	Subaru	0,84	1,06	0,79	1,15	1,15	1,00	0,69	0,77	0,90	1,62	1,65	0,98	1,08	1,54	0,70
CB17	Honda	0,64	0,74	0,87	0,79	0,91	0,87	0,78	0,88	0,89	1,02	0,89	1,14	0,42	0,53	0,79
CB18	Hyundai	1,73	2,15	0,80	1,60	1,68	0,95	1,37	1,49	0,92	0,82	0,84	0,98	3,19	4,48	0,71
CB19	Land Rover	0,79	0,95	0,83	4,17	4,25	0,98	0,28	0,30	0,96	2,44	2,41	1,01	2,48	2,89	0,86
CB20	Chevrolet	0,95	0,88	1,08	0,07	0,06	1,16	0,61	0,73	0,83	6,68	5,85	1,14	0,21	0,22	0,96
CB21	Porsche	1,61	2,04	0,79	1,82	1,83	0,99	0,85	0,94	0,90	1,88	1,81	1,04	4,55	6,38	0,71
	Average	**0,99**	**1,03**	**0,97**	**1,37**	**1,37**	**1,01**	**0,99**	**1,14**	**0,88**	**1,35**	**1,26**	**1,05**	**1,38**	**1,62**	**0,91**
	Max	**1,75**	**2,15**	**1,24**	**4,17**	**4,25**	**1,16**	**1,81**	**2,17**	**1,06**	**6,68**	**5,85**	**1,17**	**4,55**	**6,38**	**1,16**
	Min	**0,51**	**0,55**	**0,79**	**0,07**	**0,06**	**0,84**	**0,28**	**0,30**	**0,81**	**0,56**	**0,55**	**0,93**	**0,21**	**0,22**	**0,70**
	S.D.	**0,37**	**0,44**	**0,15**	**0,75**	**0,77**	**0,10**	**0,34**	**0,40**	**0,06**	**1,30**	**1,14**	**0,06**	**1,01**	**1,43**	**0,16**

Considering total MPI first, the summary results at the lower part of Table 5.3 reveal that there has been productivity growth in the Norwegian passenger car market in the years of the study period (2008-2012). The average total productivity for all the car brands is observed to be 38%. According to the Malmquist index; about 62% of the brands (13 out of 21 brands) show an increase in their average annual productivity (since $M_t^i > 1$), whereas the remaining brands have a productivity score that varies from 21% to 89%.

Assessing the results for the periods 2008-09, 2009-10, 2010-11 and 2011-12, we can observe some remarkable trends with regards to productivity changes between brands. First, there is evidence of regression by 1% shown in both of the periods 2008-09 and 2010-11. Thus, this implies there has been a decrease of 28% in terms of average productivity as compared to the period before (2009-10). Furthermore, there is evidence of progression in 2009-10 and 2011-12 by 37% and 35% respectively.

In view of TEC^i , Table 5.3 indicates that on average, efficiency change has been a progression of about 62% from 2008-12. Actually, the average efficiency change in all the time periods shows an improvement. Thus, the progress in TEC^i is found to be 3%, 37%, 14% and 26% for the periods 2008-09, 2009-10, 2010-11 and 2011-12, respectively. It should however be accentuated that a judgment based on the average of efficiency change alone may be incorrect and misleading as data contains some outliers (i.e. Hyundai, Land Rover and Porsche). This is evidenced by a lower value of efficiency change obtained after interpolating data in Excel for these outliers based on the two previous time periods (2010-11 and 2011-12). Thus, the car market on average is seen to be 14% technically efficient, a value so much lower than 62% as portrayed in Table 5.3. Nevertheless, it can be observed that on average, the frontier shift (FS^i)

regressed 9% from 2008-12 even though a progress is observed in the periods 2009-10 and 2011-12 by 1% and 5% respectively.

Since MPI is a product of efficiency change and frontier shift indexes, a conclusion may be drawn based on the results that the major reason for productivity growth in this car market has been the technical efficiency change. This may be due to high sales of electric cars over the past few years. As mentioned earlier, the high initial investment costs for electric cars has started to pay off in the Norwegian passenger car market, as it may not be obvious but in 2009 automakers incurred high costs and low sales. However, after 2010 many brands have taken advantage of the new technology and increased their variety. For example, Nissan was one of the few brands to have invested in electric cars, which may have significant losses in 2009, but after 2009, the company's productivity has significantly improved. This is evident in the boom of sales of Nissan Leaf, one of its models that even became the most sold model in September 2013 with about 145% increase in sales (NissanNews, 2014).

5.3 Impact of exogenous variables on the car market's performance

The impacts of exogenous variables on the performance of Norwegian passenger car market will now be considered. These impacts are examined in a second-stage DEA analysis where the aforementioned variables are regressed on the efficiency and productivity scores. The extent to which these exogenous variables may lead to the efficiency of some car brands is seen in the results of the coefficients indicated in Tables 5.4 and 5.5 below. It is important to take note that a cross-section of all years was used, resulting to a total of 105 observations [21 × 5] being analysed[15].

Table 5.4: Truncated regression of exogenous variables on the efficiency of Norwegian car market

```
Truncated regression
Limit:   lower =          0                          Number of obs =     74
         upper =          1                          Wald chi2(4)  =  25.56
Log likelihood =  23.568431                          Prob > chi2   = 0.0000

------------------------------------------------------------------------------
         VRS |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     Chassis |   .0579106   .0258712     2.24   0.025     .0072039    .1086173
      Engine |  -.0432968   .0180161    -2.40   0.016    -.0786076    -.007986
  Horsepower |   .0392852   .0098995     3.97   0.000     .0198825    .0586879
   age_brand |   -.002453   .0012287    -2.00   0.046    -.0048612   -.0000448
       _cons |    .122158   .1272694     0.96   0.337    -.1272854    .3716014
-------------+----------------------------------------------------------------
      /sigma |   .2158179   .0264968     8.15   0.000      .163885    .2677507|
------------------------------------------------------------------------------
```

It is worth mentioning that a truncated regression model is used in this case due to the bounded nature of DEA whose range of values is substantially restricted. Thus, DEA efficiency scores are typically defined on the interval [0, 1], where the scores are truncated to the left at zero and to the right at one. It is for this simple reason therefore that the traditional regression analysis that assumes data to include values below zero and above one wouldn't have been appropriate in this study. For previous analyses of this type of regression analysis, see for instance Simar and Wilson (2007) and Odeck (2006, 2008).

[15] However, truncated regression was run on 74 and 84 observations on the two models, respectively (see Figures 5.4 and 5.5) as the others were removed through stepwise truncated regression due to their insignificance.

Looking at the results in Table 5.4, it is observed that the probability of obtaining the chi-square statistic given that the null hypothesis is true (Prob>chi^2) has a p-value of zero, which is less than the alpha (critical value) of 0.05[16]. This deduces that the whole model is statistically significant. Further analysis based on these results indicates that all the exogenous variables in this model have a significant impact on the efficiency of car brands in the Norwegian passenger car market. Looking at their coefficients for example, chassis has a p-value of 0.03, which is less than 0.05, hence significant. The same applies to engine, horsepower and age of brand whose p-values are 0.02, 0.00 and 0.04, respectively. These results are interesting as it shows that these variables contribute to increased and decreased[17] inefficiency in one way or the other. Put differently, since the coefficients of chassis and horsepower is positive, this implies that these variables contribute to decreased inefficiency and the opposite is true for engine and age of car brand.

In overall, from these results, it can be deduced that product variety in terms of chassis and horsepower[18] could enhance efficiency. This means that a car brand that provides a variety of chassis and horsepower is likely to perform better relative to those that have less number of chassis and horsepower. On the flip side, engine proves to be detrimental to efficiency performance implying that even if a brand provides different types of engines to the market, it doesn't gain efficiency as a result of it. It is surprising however that age of a car brand[19] has a negative coefficient and hence impacts efficiency negatively. A caution must be taken nonetheless in interpreting this result. First, an older brand should imply high efficiency due to the fact that the older the brand the more experienced it is over time. As a result, it means that particular brand is able to hold its costs at a minimal level while at the same time improving its quality (introducing new products i.e. product variety), which eventually improves efficiency. On the other hand, the older the brand the fewer the sales as the trend might be changing to having high demand in the new brands and not the old ones. This might lead to inefficiency as operating costs might be higher than the profit.

The results of the regression analysis based on productivity scores are displayed in Table 5.5 below. It is important to note that the productivity scores, unlike efficiency scores, are only truncated from below at zero.

The results shown in Table 5.5 reveal that both variables (fuel type and engine) are significant with negative coefficients. This entails that these variables explain the impact of product variety on the productivity of car brands in the Norwegian passenger car market. The negative sign on the coefficients of both variables imply that they have a negative impact on productivity. In other words, fuel type and engine contribute to decreased productivity of car brands. In this study, both variables measure product variety and this means that product variety reduces productivity. This seems logical as high product variety implies high costs. Thus, there is a trade-off between high level of product variety and high cost, which may eventually lead to less productivity of car brands.

[16] The p-value, which is compared to a specified alpha level, is usually set at 0.05 or 0.01. In this study, it is set at 0.05.

[17] If the exogenous variables are regressed on the efficiency scores, then if a coefficient of a variable is positive (negative), it means that the variable increases (decreases) efficiency. The opposite is true if regressed on the inefficiency scores (1-E).

[18] Engine is also a measure of product variety in this study, but this conclusion is drawn based on the results obtained where engine indicates a negative influence on the efficiency of car brands.

[19] Age of car brand in this study implies how long the brand has been on the market.

Table 5.5: Truncated regression of exogenous variables on the productivity of Norwegian car market

```
Truncated regression
Limit:   lower =          0                          Number of obs =     84
         upper =       +inf                          Wald chi2(2)  =  11.78
Log likelihood =  -82.15462                          Prob > chi2   = 0.0028

------------------------------------------------------------------------------
         MPI |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   Fuel_type |  -.8593687   .3752596    -2.29   0.022    -1.594864   -.1238735
      Engine |   -.065448   .0379711    -1.72   0.085      -.13987    .0089741
       _cons |   3.343228   .7009569     4.77   0.000     1.969377    4.717078
-------------+----------------------------------------------------------------
      /sigma |   .9474844   .1306042     7.25   0.000     .6915049    1.203464
------------------------------------------------------------------------------
```

5. CONCLUSIONS AND POLICY IMPLICATIONS

This paper contributes to the literature on efficiency and productivity measurement in the Norwegian passenger car market by employing DEA and Malmquist indices to measure efficiency and productivity, respectively. The assessment is based on output-increasing technical efficiency that focuses on how efficient car dealers are in augmenting their output while keeping the level of inputs constant.

The results show that there is potential for efficiency improvement in the Norwegian car market, and this potential varies largely among all the car brands. Thus, on average, car brands have about 40%, 65% and 38% potential for efficiency gains in light of variable returns to scale, constant return to scale and scale efficiency, respectively. One interesting observation is that most car dealers (about 76% of the car brands) seem to be highly inefficient in 2009. This may be due to the economic crunch as well as political pressure on brands to develop their technology on electric cars as the Norwegian government had introduced monetary incentives. Further, there are economies of scope in this car market as is seen by many car dealers offering higher variety (various car models) to many segments in the market.

Concerning productivity, there is a progress in productivity by 38%. Such an increase in productivity owes its explanation to the car dealers being able to utilize their resources efficiently and this is mainly seen in the 'catching up index' of the MPI that has a progression of about 62%. In sum, a conclusion may be drawn that the major reason for productivity growth in this car market is the technical efficiency change, which tends to outweigh the frontier shift as it shows a regress in the frontier technology by 9% within the same time period.

Nevertheless, the regression analysis indicates that inducing product variety has two-fold effects. Thus, high product variety increases efficiency and at the same time reduces productivity. The possible reason for this contradiction might be due to the fact that efficiency scores are only one component of total productivity and that factors affecting efficiency scores in terms of product variety (e.g. chassis and horsepower) haven't significantly impact total productivity. This is seen clearly in both models where despite being significant, they have different exogenous factors that are impacting product variety differently.

An obvious policy implication for decision makers based on the findings of this paper, is to provide the managers with the potentials for efficiency improvements that they may strive to obtain even though the whole potential may not be possible to achieve. Since efficiency and

productivity are relative measures, the managers may learn from their peers that have been found to be efficient by learning what they do to be so efficient. For instance, product variety is found to enhance efficiency and managers may be urged to enhance product variety as means of increasing their sales and hence become more efficient.

ACKNOWLEDGEMENTS

The authors thank Molde University College for providing us with Norwegian car market data, which was bought from Opplysningsrådet for Veitrafikken. However, the views expressed in this article are merely the authors' and none should be accredited to the above named institution.

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Sustainable and responsible freight transport through public-private collaboration

Finnish road freight responsibility model

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ABSTRACT

Purpose

In aviation, maritime and rail transport safety management systems are well adapted and they are fixed part of daily practices and the minimum requirements for systems are set in European regulations. However, this does not apply a road freight sector. In 2013, Finnish Transport Safety Agency (Trafi) started to develop a road freight responsibility model, which was intended to enhance safety, quality and environmental management in the Finnish road freight transport sector. The aim of this paper is to introduce the Finnish model and to summarize the main findings from the responsibility model.

Approach

This paper includes data and knowledge from two separate but related projects which studied responsibility and sustainability in the Finnish road freight sector. The paper combines information from several methods, but the main research method was a case study with transport companies. Complementary methods used in this paper are workshop and online survey.

Findings

Transport companies have different practises and attitudes related to the responsible business and the size of the company or the main service sector of the company do not always explain the differences. According to the results, this kind of new voluntary basis approach has a demand in the road freight sector and it will provide help for transport companies to develop their business.

Value

The paper represents a new approach of the national transport agency to develop the road freight sector. With the responsibility model Trafi aims to promote sustainable and responsible business of all sizes of transport companies with a voluntary basis approach.

Keywords: Heavy road freight, sustainability, transport management, transport agency, Finland, safety, quality, environment, responsibility.

1. INTRODUCTION

Road freight transport is an essential part of the current everyday trading system and without a seamless and efficient road freight transport system the economic competitiveness and social welfare are threatened. In Finland, road freight covers about 90% of total goods transported, when measured in tonnes and about two third of the total transport haulage (tkm) (Statistics Finland, 2012). From the total Finnish road haulage, the professional transport accounts for 93.5% (Statistics Finland, 2014). However, at the same time road freight sector has significant negative impacts on the environment and road safety, since the road freight transport causes about 25% of the total road transport CO_2 emissions, 38% of nitrogen oxides and 24% of fine particle emissions, for example (VTT, 2013).

Heavy road freight covers only about 6% from the total driven kilometres in Finnish roads, but trucks are involved in 24% of fatal road traffic accidents. From the road accidents where at least one vehicle was involved and which led to the injury trucks cover only on 5%. In 2012, 255 people died in the road traffic and eight of them were truck drivers and two were truck passengers, but in addition trucks were involved in 89 people fatal traffic accidents. (Liikenneturva, 2013)

In addition to accidental accidents, suicides are one significant challenge for traffic safety and the repetition of the truck driver profession, thus about 20 suicide car drivers cause accidents annually in Finland (Rajalin, 2011). Often these drivers collapse by truck and cause a suicide and significant mental injuries to the truck drive, which might even force the driver to stop working.

The big share of trucks in fatal accidents and emissions highlights the negative impact of trucks on the road traffic. Thus, it is essential to continuously improve and develop the safety, quality and environmental management in the road freight transport sector. And even a small improvement might save someone's life. In this paper, we present the new approach of Finnish Transport Safety Agency (Trafi) to enhance the sustainable and responsible transport by developing a voluntary based road freight responsibility model.

With the responsibility model Trafi aims to improve the safety, quality and environmental management of transport companies of all sizes and to improve the collaboration and understanding between hauliers and shippers. The model is based on voluntary implementation and with it Trafi offers practical tools for the transport sector to develop their operations.

Taniguchi et al. (2014) presents that the role of the government in developing urban freight transport can be divided into four stages: 1. identifying problems, 2. finding approaches and measures, 3. implementing policy measures and 4. evaluating policy measures. Active communication between stakeholders combines these four stages together. The same approach can be expanded to the whole transport sector. However, with responsibility model Trafi as a public organisation does not try to develop the transport sector with legislation or typical policy actions. Instead Trafi, aims to develop the transport sector via voluntary actions by offering operators a management tool which encourages operators to develop their operations.

The model is primarily developed for transport companies but it also offers knowledge and tools for the shipper-haulier interface. The role of shippers in complex logistical chain is highlighted in this approach since shippers can act as a driving force in developing the whole transport sector towards responsible operations. However, currently there lies ignorance, indifference and lack of understanding in logistic chain on how to develop responsible and sustainable freight transport. This can be seen from previous studies where only 5-15% of the

hauliers report to shippers about their fuel consumption and only 18% of the transport companies reported that their customers have been interested in the energy efficiency actions of the company (Liimatainen et al. 2012).

The model consists of general instructions for transport companies how to develop their own responsibility in transport business, example documents for companies to help in reporting and monitoring and a user interface which helps companies to monitor their monthly business operation activities. The model is developed to answer following research questions:

- What kind of voluntary based responsibility management system would fit all sizes of transport companies?
- How can the model offer maximal benefits for transport companies in relation to required resources?
- How can the model be attractive for transport companies and for shippers?

2. RESPONSIBILITY MANAGEMENT SYSTEMS IN ROAD FREIGHT TRANSPORT

Several widespread safety, quality and environmental management systems are available for use also in the road transport sector. Islam and Zunder (2014) found that major ISO management standards, ISO 9001 for quality management and ISO 14001 for environmental management, are well known and useful in logistics. There are also several specialized transport and logistics standards, such as ISO 39001 (road traffic safety), EN 16258 (calculation and declaration of energy consumption and GHG emissions of transport services) and EN 12798 (transport quality system). However, the road freight transport sector consists mainly of very small companies, which do not have the resources to implement major management systems. Hence, responsibility models which are easy to implement have been called for and developed.

According to Islam and Zunder (2014) government should internalize the externalities of logistics, such as environmental and accident costs, and intervene if unfair competition is detected, but the quality of logistics should be left to determine between shippers and operators. Hence, voluntary responsibility models, which help shippers and operators work together towards safe, sustainable and high quality logistics are more preferable than legislative measures. However, the shippers have a very significant role in the development of this kind. Since if they are not willing to pay extra or if they are not interested in supporting more responsible and sustainable transport operations, the goal is very challenging to achieve by transport companies alone.

The EU Commission's Freight Transport Logistics Action Plan (COM/2007/607) called for a collaborative effort between stakeholders for the establishment of "a core set of indicators that would best serve the purpose of measuring and recording performance (e.g. sustainability, efficiency, etc.) in freight transport logistics". Such set of key performance indicators was developed in the UK during the Freight Best Practice programme. The "Key Performance Wheel" provides examples of the most important indicators of various aspects of freight transport operations, including transport and warehouse operations efficiency, sales and marketing, customer service and legal compliance (DfT 2007).

Less comprehensive and more environmentally oriented tools include the US Environmental Protection Agency's SmartWay Truck Carrier Partnership which collects benchmarking information on the environmental performance of freight transport operators and shippers (EPA 2015). Transport for London has developed a "London Fleet Operator Recognition Scheme (FORS)", which is a voluntary accreditation scheme aiming to improve fleet activity (TfL 2015). Through accreditation operators receive guidance on efficiency, environmental and health and safety issues. The scheme has three accreditation levels according to the implementation of best practices and reporting of their effects. The London FORS provides an example how government can promote responsible practices through a voluntary scheme.

3. METHODOLOGY

The development of the Finnish responsibility model was started in 2013 and the first project ended at the 2014. The development continued later in 2014 and the second phase ended in January 2015. During the development several research methods have been used to gather knowledge about practices and attitudes on responsibility in the road transport sector. The combination of different methods enables studying interests of different road freight stakeholders which all have an important role in logistics. The main research method in both study phases has been a continuous case study, which has ensured a close collaboration between transport companies, Trafi and the research group. The first phase also included a workshop and shipper survey which provided valuable information on the contents of the model.

Multiple research methods have been used to gather knowledge about different aspects of responsibility in freight transport. The case studies focused on the development of the responsibility model from the operational point of view and wider perspective was gathered with the online survey and the workshop. The results from the survey and the workshop were used as an input to case study and vice versa. The survey also provided beneficial information for further development of the responsibility model where the development should focus more on the interface between transport companies and shippers.

3.1. Case study

The responsibility model is developed in a close co-operation with road freight transport companies. In the first phase (2013-2014) six companies were engaged in the project and in the second phase (2014-2015) the same six companies and three new companies participated in the project. The transport companies represent different sizes and various service sectors, because the main aim of the model is to serve transport companies of all kind.

At the beginning of the projects, all the companies were interviewed, with face-to-face interviews, about their practices and attitudes towards responsible business in the road freight sector. Later during the projects companies were interviewed again with telephone interviews. Both the face-to-face and telephone interviews were organized as an open theme interview and thus this method allowed an open-minded approach to the topic. During the interviews, the case companies gave feedback about the model in overall and they pointed out which parts or measures of the responsibility model they evaluated as the most important and challenging from the point of view of the development of the national road freight sector.

During the project, the companies' main duty was to test the model and give feedback about the usability and the benefits of the model. Companies' task was also to report monthly about their operation by filling the model and sending it via email to the researchers. However, the response rate in monthly reporting varied between companies, when some of case companies

reported monthly some companies reported only once during the project. In emails, companies were able to give feedback and new development ideas to the project group.

According to the feedback, all the most important measures were included in the model in co-operation with case transport companies and other stakeholders during the first phase. The second phase of the development of the model focused on the usability of the MS Excel tool and to gather the knowledge about responsible transportation especially in the whole logistics chain a point of view. During the second phase, the Excel tool was updated to enable a comparison of different months and annual averages. All of the example documents were also updated and a short introduction was included in the documents.

3.2. Workshop

In addition to the case study method, a workshop for road freight stakeholders and an online survey for the shippers were organized during the development of the responsibility model. In the responsibility model the sustainability and responsibility are dived in three subcategories: safety, quality and environment. This categorization is made to clarify the study, because responsibility is a multi-dimensional topic which can be approached from various perspectives. Each of these subcategories contains different responsibility related measures. Some of the measures could belong to more than one subcategory but in this study classification used is presented in Table 3.1. The same classification was used also in the workshop and online survey.

Table 3.1. Responsibility measures examined in workshop and shipper survey.

Safety	Quality	Environment
Carriage loss	Accuracy percent of transportation	Average consumption
Pre-trip inspection	Quality standards	Carbon dioxide emissions
Driver instructions	Revenue	Energy efficiency
Ignition interlock devices	Service plan of vehicles	Environment standards
Near misses	The level of driving style	EURO-classes of vehicles
Number of cases of vandalism	Tonne-kilometres	Fuel consumption
Other accidents	Total mileage	Low-carbon fuels
Safety standards	Training of staff	Measures minimizing fuel consumption
Traffic accidents	Training plan	
Traffic accidents with injuries	Transportation volume	Membership of energy efficiency contract
Traffic violations	Well-being of staff	New motor technologies

The workshop was organized in the end of October 2013. In total 30 people participated in the workshop and 11 of them were members of project group or the steering group of the project. The rest of participants represented case companies and other transportation stakeholders mostly from the road freight transport lobbying organizations. At the beginning of the workshop guests (19 people) were asked to fill a questionnaire where participants prioritized the different responsibility measures presented in Table 3.1.

In the workshop, all the participants were divided in four small groups and in every group there was one member from the project group. All the groups had the same assignment: which of the responsibility model measures are the most important and why, and how the responsibility management of transportation can be developed. In the small groups, answers of the initial questionnaire were used as a basis for discussions.

All four groups gathered their own view about the most important responsibility measures and suggestions for the best practices to develop the responsibility management in transportation. At the end of the workshop, all the results were presented by the member of the project group and during and after the presentations participants had opportunity to discuss the results.

3.3. Shipper survey

The survey was sent more than 300 Finnish shippers and in total 30 of them responded. The aim of the survey was to reach as many different industries as possible in order to obtain good general understanding about shippers' attitudes and practices of the safety, quality and environmental management. The survey included open and multiple choice questions, which focused on the practices of companies in responsible and sustainable transportation, such as standards and certificates. With the multiple choice questions respondents evaluated how important they see different responsibility measures from the shipper's point of view.

In total respondents represent eight different industry sectors and both large and small companies. The main business of nine respondents was logistics and also nine respondents represent the chemical industry, three of the respondents represent the metal industry, three were from the trade sector and from the forestry sector, construction sector, service sector and from the public sector only one from each.

The turnover of the companies was from less than 1 million euro to 5 billion euro with the average of 420 million €. In the average companies use the services of 38 different transport companies. Shipments of 18 companies consist mostly of general cargo and for five company shipments are operated mainly by tank trucks. Three of the respondents answered "other" as their main type of shipments and waste disposal, dry bulk goods and container/demountable platform/swap body shipments received a single response each. Half of the shippers also require ADR shipments.

4. RESULTS

The results of the shipper online survey and the workshop highlighted the gap between the attitudes of shippers and transport companies. The survey and workshop also produced significant intermediate results for the content and the frame of the Finnish road freight responsibility model which was continuously developed and tested with the case transport companies. The results of the survey and workshop are presented more detailed in chapters 4.1, 4.2 and 4.3. The chapters 4.4 and 4.5 describe the results of case study and represent the current version of the responsibility model.

4.1. Shipper online survey

According to the results of the survey, most of the shippers are using safety, quality and environment standards, but at the moment they do not require the transport operators to implement the same standards. Shippers mostly do not require any standards or they only partly require standards from the transport companies. However, three standards are the most commonly used by both shippers and operators: Quality Management Systems Certification

(ISO 9001), Environmental Management Systems (ISO 14001) and Occupational health and safety management systems (OHSAS 18001). As the most important reasons to use and to require standards shippers see improvement in operational reliability, customer requirements and improvement of the image of the company.

According to the responses almost two thirds of the shippers have set some specific requirements for the hauliers, e.g. minimum EURO-class level for the vehicles, responsibility to report about the delays or a tax certificate. However, 37% (11) of the respondents have not set any external requirements for the hauliers, which enables an independent operation for the haulier, both in good and bad. If the shippers are only interested to move good from A to B, it does not encourage transport companies to develop their business.

In the survey, all the respondents evaluated which responsibility measures are the most important from their point of view. In the survey, the measures were divided into three categories: safety, quality and environment as shown in Table 3.1. Below in the Table 4.1 are listed the Top 10 measures according to the mean value.

Table 4.1. Averages of the Top 10 measures in the online survey (0=unnecessary,… 3=very important)

Top 10 measures	mean	ranking
Carriage loss	2.7	1
Accuracy percent of transportation	2.6	2
Driver instructions	2.6	3
Traffic accidents with injuries	2.4	4
Quality standards	2.3	5
Traffic accidents	2.3	6
Safety standards	2.3	7
Environment standards	2.2	8
Transportation volume	2.1	9
EURO-classes of vehicles	2.1	10

The Top 10 list highlights how important the shippers consider the quality of the transportation, as the carriage loss and accuracy percent of transportation are evaluated in the three most important measures. The result is not surprising, thus the shippers want their goods to be transported in right time without any damages, because a delay or damage to transportation will always cause some extra work and money.

The shippers also evaluated all three different standard classes in the Top 10. This might be due to the reputation of different standards and because standards are quite easy to check. However, according to the interviews that were done during the projects the names of the different standards are quite well known by the stakeholders, but the contexts of the standards are not clear for all of the stakeholders and especially for the small companies. Thus it raises the question that are some of the standards just gained to enhance of the reputation of the company.

The Top 10 list indicates the lack of interest towards the environmental issues. According to the survey, the shippers evaluate environment measures the least significant when compared with the quality and safety issues. The membership of the energy efficiency contract for example was evaluated the least significant in the total listing and energy efficiency (tonne-kilometre/kilowatt-hour) was 24th and CO_2 emissions 22nd.

In addition to the environment standards, the Euro-classes of the vehicles are the only environmental measure in the Top 10 list. One reason why the environmental measures are not appreciated by the shippers might be that environmental measures are quite new in transport sector and for example the amount of CO_2 consumed does not tell much for the shippers. This is also in line with that that EURO-classes of the vehicles is in the TOP 10, thus EURO-classes have got a lot of media attention because the stricter emission control and because of the new EURO VI class which came into force 2013. In addition, EURO-classes clearly indicates for the shippers how old the truck fleet the transport company is using.

4.2. Workshop

In the questionnaire, participants assessed the traffic accidents with injuries, traffic accidents, fuel consumption and driver instructions as the most important responsibility measures in the road freight sector (see Table 4.2.). In small group discussions, participants highlighted the importance of the publicity of the positive outcomes of responsibility actions to develop the responsibility in the whole transport sector. And if the positive outcomes of responsible business can be shown as a monetary value the more effective the message would be. However, the participants also believed that the general opinions about responsible business will also be a very important motivator for transport companies to develop their business. Thus, the role of shippers and other interest groups can be seen as a very important factor while trying to develop the road freight transport sector.

Table 4.2. Averages of the Top 10 measures in the workshop (0=unnecessary,… 3=very important)

Top 10 measures	mean	ranking
Traffic accidents with injuries	2.9	1
Traffic accidents	2.8	2
Fuel consumption	2.8	2
Driver instructions	2.7	4
The level of driving style	2.7	5
Average consumption	2.7	6
Carriage loss	2.7	7
Service plan of vehicles	2.6	8
Traffic violations	2.6	9
Well-being of staff	2.6	10

4.3. The comparison between the results of survey and workshop

The results of the workshop and the survey establish that there is a difference in the safety, quality and environmental management attitudes between these two different road freight stakeholders. Below in the Table 4.3. are the safety, quality and environmental management measures which got the greatest difference in the online shipper survey and the workshop. The minus sign before the deviation value indicates that the measure has been ranked less important in the workshop than at the online shipper survey. In generally, while shippers appreciate the quality of the transportation, the hauliers want to focus on safety and fuel consumption. Money is definitely one explanation for this difference, thus shippers do not want any damage or delays for their transportation as it will cost more for them and at the same time transport companies want to cut down operational costs.

Table 4.3. The Top 5 differences between the results of the survey and workshop.

Deviation of the measures valuation	deviation	ranking in survey and workshop
Quality standards	-21	5/26
Environment standards	-18	8/26
Accuracy percent of transportation	-17	2/19
Pre-trip inspection	17	31/14
Traffic violations	16	25/9

The greatest differences in between the values of the survey and the workshop are in the quality and environmental standards. The difference highlights how much stakeholders opinions differ from each other. While the shippers ranked both of these standards in the top 8, in the workshop these were ranked as a one of the last important measures. Almost as large difference is also in the accuracy percent of transportation measure, which was the second most important measure from the shipper's opinion and only 19th in the workshop. On the other hand, the participants of the workshop ranked the pre-trip inspection measure in the middle of the scale and the shippers the least important and almost the same difference applies the traffic violations measure. This indicates that the shippers are not much interested how they got their goods as long as they got it.

Below in the Table 4.4. are presented those measures where the results of the survey and workshop were consistent. The deviation is calculated at the same way as it is calculated in the Table 4.3.

Table 4.4. The Top 5 similarities of the measures valuation in the survey and in the workshop.

Similarities of the measures valuation	deviation	ranking in survey and workshop
Training plan	0	11/11
Driver instructions	-1	3/4
Ignition interlock devices	-1	28/29
Membership of the energy efficiency contract	1	32/31
Tonne-kilometres	-2	17/19

According to the results, respondents consider it important that there is instruction for the driver inside the truck. However, this moves all the responsibility to the driver, since the instructions are not helping at all if the driver is not interested to use it. Respondents also ranked the ignition interlock device as a one of the last important measures, which is in line that truck drivers enjoy the trust of the transport companies and the shippers.

The only measure where the opinions are exactly equal is the training plan measure. Respondents consider is quite important as both of them ranked it 11th. This is a good indicator that the stakeholders of Finnish transport sector trust on education, which is typically a backbone for the sustainable development.

In the survey and in the workshop, the energy efficiency membership was ranged as a least important measure. This indicates that the energy efficiency as a measure is not familiar to the stakeholders although it has got a lot of media attention. According to the results, respondents consider the fuel consumption and the average fuel consumption much more important than the energy efficiency even though the energy efficiency describes more about the total transportation action than the fuel consumption.

4.4. Case study

The close collaboration with the case companies offered valuable information about the daily practices in the road freight sector. The collaboration highlighted how different practices transport companies have related to responsible business and the level of knowledge about responsible issues is not always tided to the size of companies. All of the case companies experienced that they got help and some new ideas from the responsibility model to develop their own business.

The case companies also saw that this kind of free and on a voluntary basis approach is a good method in order to develop the road freight sector. According to the feedback, the case companies believe that the responsibility model offers valuable information and concrete tools for transport companies, but at the same time it is general and simple enough so an introduction and usability of the model is easy even for the smallest companies.

4.5. The Finnish responsibility model

The current version of the responsibility model consists of general instructions and advice, the business activities tracking tool and its guidance and various example documents with a short introduction. The general introduction and advice are written to lead companies to internalize the importance and potential of the responsible business. The introduction also gives transport companies concrete hints how to develop their business more sustainable and responsible. However, the model is developed into all Finnish transport companies and thus it is impossible to go very detailed level in guidance. The introduction encourages companies to the future orientated approach in their business management and that way to be more prepared future risks and challenges.

The business activities monitoring and tracking tool is developed in MS Excel file, which consist of five worksheets: company information and fleet, filling, monitoring, development and responsibility report. The tool is divided into five worksheet to simplify the usability of the tool. For the company information and fleet and filling worksheets the user should fulfil the monthly data about the business activities. Based on the shipper survey, workshop and case study, the model was decided to include the following indicators (see Table 4.5.), which the freight operators should monitor and report monthly.

Table 4.5. Responsibility measures included in the business activity tracking tool.(Environment measures the tool automatically calculates based on reported data)

Safety	Quality	Environment
Traffic accidents	Accuracy percent of transportation	EURO-classes of vehicles
Traffic accidents with injuries	Traffic violations	Average consumption
Accidents occurred during handling and other accidents	Driving time and rest period violations	Energy efficiency
Near misses	Carriage loss	Carbon dioxide emissions
Number of cases of vandalism		
Pre-trip inspections		
Volume	**Staff**	**Company's own indicators**
Turnover	Training of staff	Own indicators 1-7
Total mileage	Sickness absence	
Transportation volume	Over the 11 hour working days	
Tonne-kilometres	Driving style	
Fuel consumption		

The monitoring worksheet collects automatically fulfilled data and enables a comparison between moths and annual averages. The development worksheet also automatically collects data from previous worksheets and draws a time series line chart each of the measures based on the reported data. The final worksheet, responsibility certificate is aimed to use as a transcript, which proofs the responsibility of the company. This one A4-size responsibility certificate must always be signed by the manager of the company or other authorized person. Based on the values the model creates a responsibility certificate, which the shippers may require and operators provide in order to verify the use of the responsibility model. The responsibility certificate includes information presented in Figure 4.1.

Responsibility certificate **4.3.2015**

Name of the company _____
Company ID _____
Address _____

Safety, quality and environmet standards

Tilaajavastuu.fi member _____

		Updated
Drivers instructions	Energy efficiency (PIHI-system)	_____
	Fleet mantenance plan	_____
	Drivers training plan	_____
	Emergency instructions	_____
	Pre-trip inspections	_____
	Deviation and near misses reporting	_____

	Responsibility measures	**annual average**
Safety	Traffic accidents with injuries (pcs/month)	_____
	Traffic accidents (pcs/month)	_____
	Accidents occurred durin handling and other (pcs/month)	_____
	Near misses (pcs/month)	_____
Quality	Driving time and rest period violations (pcs/month)	_____
	Traffic violations (pcs/month)	_____
	Carriage loss (% deliveries damaged)	_____
	Accuracy of transportation (% delivered on time)	_____
Environment	CO_2 emissions (tonne)	_____
	Energy efficiency (kWh/tkm)	_____
	Fleet EURO-class average	_____
	Average consumption (l/100km)	_____

_____
Signature and name clarification

Place and date _____

Figure 4.1. Responsibility certificate.

In addition to the tracking tool, the model includes several example documents which are developed to give new ideas and practical help how to organize monitoring and guidance in transport companies. Each of the example documents consists of a short introduction text and an example form. The example documents include emergency situation introduction, pre-trip and regular inspection instructions, orientation form for employees, deviation situation instruction, deviation reporting form, check list for risk management and an example of the fleet maintenance plan.

The aim of these example documents is to offer more information than companies typically need, so that companies can pick up the most relevant parts of the documents and develop their own instruction and reporting practices. In the introduction text companies are

encouraged to compare these example documents with company's existing documents and that way to develop their operations.

5. DISCUSSION

The transport responsibility model, developed during two projects described in this paper, try to achieve better and closer collaboration between road freight companies and the shippers. Finnish Transport Safety Agency (Trafi) will operate as a mediator between various stakeholders to progress new and more responsible operations models especially in the field of quality, safety and environment. The developed model will affect to the whole transportation chain through deeper co-operation between diverse stakeholders, especially shippers and road freight transport companies. The target for Finnish Transport Safety Agency as an authority organization is to contribute the increasing co-operation without official regulations based on voluntariness and through emphasizing the benefits gained through responsibility model. This is totally new approach in authority sector, when this kind of organization is capable for affect development of transport industry without official regulations.

This research is conducted with 9 case companies in road freight transport sector in diverse company sizes and transport sectors and they are in different stages in developing their quality, safety and environmental approaches. These case companies have performed demonstrations of new follow-up, analysing and reporting processes. The model is intended to diverse company sizes, although middle size transportation companies are the most probable user group and the group which will benefit most by developing their own performance and profitability through utilization of the transport responsibility model.

The model is more like a mindset or philosophy than operations model. It includes many aspects and targets with concrete measures, but most of all target is to change the mindset more future orientated and attitude to the quality, safety and environment approaches and therefore to improve the performance of company and increase co-operation between road transport company and shipper organizations.

6. CONCLUSIONS

The Finnish road freight responsibility model is aimed for companies of all sizes and it is based on voluntary participation. The aim of the model is to enhance responsibility and sustainability in the road freight sector, thus it is developed into work more like a business management mindset or philosophy than a concrete operations model. With the change in mindsets, Trafi aims to activate companies to improve their daily practices and to develop their transportation business. The model does not require companies to use some specific methods or systems, vice versa companies can use their own systems and practices and adapt first those parts of the model which are the most relevant to the company.

The purpose of this paper is to describe how the public sector can develop private sector with a new kind of approach where voluntary based management model is offered to transport companies to develop their own responsibility. The responsibility model is developed in a close collaboration between private and public sector and the collaboration has established that this kind of new voluntary based approach is a potential way to develop the whole national freight transport sector. The responsibility model consists of the most relevant sections of safety, quality and environmental transport management, the combination of

which supports transport companies to prepare for future risks and challenges and to enhance their collaboration with the shippers.

The current version of responsibility model includes several general example documents for reporting and monitoring and a Microsoft Excel based tracking tool for monthly business activities monitoring. With the monthly monitoring and example documents Trafi aims to improve responsibility and the future orientated practices in the transport sector and to encourage transport companies to focus and improve their own responsibility. According to the feedback, the model has been successful in this, since the case companies have found the example documents and activities tracking tool useful and they have reported that the model has encouraged them to develop their operations during the research projects.

Although the model is developed especially for the road freight transport companies, Trafi aims to improve the responsibility in the whole logistics sector. The vision is that with this voluntary based approach transport companies are more interested in developing their own activities and are that way more enlightened to negotiate with logistics shippers. In future, the focus on the development of the model is also planned to shift more on the shippers' side of the logistics chain, which should intensify the interface between transport companies and shippers.

ACKNOWLEDGEMENTS

This paper is based on the Road freight transport responsibility model studies which were funded by Finnish Transport Safety Agency and conducted in Tampere University of Technology in fruitful co-operation with the case transport companies and workshop and online survey participants.

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Recommendations towards enhancing Supply Chain Visibility in the pharmaceutical industry

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ABSTRACT

Purpose
The aim of this paper is to analyse the pharmaceutical industry in terms of supply chain visibility. Here, legislative regulations constitute enormous challenges for firms. The purpose is to recommend visibility improvements by automatic identification technologies.

Design/methodology/approach
Regarding the purpose of the study, a qualitative data analysis with ten case studies were conducted. Therefore, different companies along the pharmaceutical supply chain served as a source.

Findings
The paper shows that interpretation difficulties of the Good Distribution Practice guideline and process complexity require further supply chain visibility mechanisms. Improvement possibilities, e.g. securPharm with passive RFID tags or containers with sensor nodes, are derived within the study to conduct visibility improvements.

Research limitations/implications
This study is limited to the pharmaceutical industry in Germany. Furthermore, the study focuses on a certain supply chain path within this complex market, and is therefore not intended to be exhaustive. Thus, the results serve as a foundation for further analysis.

Practical implications
Against the background of regulations and complexity, the use of the technological recommendations can help to increase supply chain visibility. Furthermore, practitioners get to know an overview of points along the supply chain for improvements possibilities.

Original/value
The paper gives an overview about the pharmaceutical supply chain in Germany and detailed insights into a specific path within this chain. Based on these detailed practical insights, three improvement approaches for enhanced supply chain visibility were derived.

Keywords: supply chain visibility, pharmaceutical industry, automatic identification technologies, qualitative data analysis, supply chain management.

1. Introduction

Global procurement channels, international production sites, various contract service providers, as well as many other players in the pharmaceutical supply chain lead to increasingly complex and highly interconnected value creation networks (EU, 2013). These structures constitute a challenging environment for companies. Due to these challenges, there is a need for transparency along the supply chain which is also known as Supply Chain Visibility (SCV). This SCV represents a crucial factor for an enhanced overview about the flow of materials and information within branched supply chains (Christopher and Lee, 2004). Further reasons for the importance of SCV are dynamic markets, legal requirements, and security aspects that have to be fulfilled. Therefore, it is even more important to monitor products along the entire value chain.

A variety of guidelines support the actors in the pharmaceutical supply chain to cope with current complexity, and to ensure a correct and rule-consistent handling of medical products (EU, 2013). The latest guideline for Good Distribution Practices (GDP) of Medical Products for Human Use of the European Union is effective since September 2013, and constitutes enormous challenges for the pharmaceutical industry in terms of SCV (Spiggelkötter, 2013). Errors in production and distribution of drugs, and an increasing number of product counterfeiting justify the high requirements of such guidelines (WHO, 2014). Following on, product counterfeiting, theft, and faulty drugs due to incorrect or ineffective ingredients lead to multi-billion-dollar revenue losses everywhere. Besides the economic losses, the damage of health by incorrect, ineffective, or missing ingredients in the drugs is far more threatening.

For these reasons, the creation of an end-to-end SCV for drugs along all players in the pharmaceutical supply chain becomes even more important, also with respect to cost optimization (UPS, 2013). Furthermore, current available methods and IT-systems do not enable a unique status description of drug manufacturing and distribution processes, as well as their environmental conditions (see section 2.2.3.). So currently from our point of view, there is no possibility for a consistent end-to-end visibility. But the equipment of objects with technologies for automatic identification (Auto-ID), such as RFID tags or sensor nodes, with localization possibilities (Majordomo et al., 2011; Miles, 2008; Mullen and Moore, 2006; Reyes, 2011; Sanchez Lopez, 2011) can help to achieve the aim of enhanced medicine transparency along the supply chain, and to reduce and manage complexity.

Against this background, the authors see a great potential for transparency improvement by the application of Auto-ID technologies. Based on current challenges in terms of SCV, the aim of this paper is to enhance SCV within the pharmaceutical supply chain by deriving suitable improvement approaches. So in this context, the central research question is: how can Auto-ID technologies improve SCV within the existing pharmaceutical supply chain?

To answer the research question, the paper is organized as follows. Chapter 2 explains the fundamentals of SCV, and the pharmaceutical supply chain. The research methodology is described in chapter 3, while chapter 4 presents the results of our qualitative study. The paper ends with a conclusion, limitations, and implications for further research.

2. SCV and the pharmaceutical supply chain

This chapter is divided into two parts. The first part explains the basic thoughts of SCV within Supply Chain Management. Chapter 2.2. presents the pharmaceutical supply chain, and current applied SCV approaches.

2.1. Supply Chain Management and Supply Chain Visibility

A first application and definition of the Supply Chain Management (SCM) concept goes back to Oliver and Webber (1992). Over the time, different researchers defined SCM whereas a central thought can be seen in the management of complex business relationships (Christopher, 2011; Mentzer et al., 2001). In this paper, the authors follow the definitions of Mentzer et al. (2001) and Christopher (2011). Thus, SCM is defined as: "[…] the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long term performance of the individual companies and the supply chain as a whole." (Mentzer et al., 2001, p. 18) and "The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less costs to the supply chain as a whole." (Christopher, 2011). Consequently, SCM regards collaborating companies as a part of networks to satisfy customer needs. Besides, the management activities should result in performance optimization and cost reduction.

A major challenge in the context of SCM is the Bullwhip effect (Chen et al., 2000; Christopher, 2011; Lee et al., 1997a; Lee et al., 1997b). This effect describes the disproportionate production growth in terms of increased demand. The reason for this inappropriate behavior was traced back to a lack of cross company information sharing. The resulting paucity of information lead to inefficiency and demand volatility along the whole supply chain. Besides, the current turbulent business environment influences SCM (Christopher and Holweg, 2011). Here, the globalization, increased customer requirements, and shorter product life cycles are challenges which lead to a rethinking of traditional SCM activities and supply chain structures. Following this, supply chain managers have to focus on flexibility, and on adaptable structures to cope with the aforementioned challenges. For that reason, information sharing between all actors within a supply chain is a very important task in order to cope with the volatile markets (Christopher and Holweg, 2011; Holcomb et al., 2011).

Given this perspective, the authors see a need to expose with supply chain visibility. SCV is a concept which enables the tracing of goods from sources to sinks through transparency (Levans, 2013). This includes all processes from the supply over the production to distribution. Regarding the current research work of SCV, Klueber and O'Keefe (2013) and Caridi et al. (2014) give an overview about SCV definitions. Against the background of this research focus on enhanced drug visibility along the supply chain, the authors do not focus on one definition. They are emphasizing the determination of unique identification, current position, and status quo of objects which move along the supply chain. Furthermore, these information should be permanently available for all actors within the supply chain, and support monitoring, controlling, and decision making of SCM. Thus, the realization of SCV achieves a reduction of the Bullwhip effect through higher transparency about the demands of collaborating supply chain actors. Additionally, the possibility of a continuous tracing of objects can be optimized and the protection of product originality which is particularly crucial for the pharmaceutical industry.

2.2. The pharmaceutical supply chain and current SCV approaches

To enhance the understanding of the pharmaceutical industry, section 2.2. shows the pharmaceutical supply chain with its relevant actors. Furthermore, current challenges, and applied approaches for SCV are explained.

2.2.1. The pharmaceutical supply chain

In short, the pharmaceutical market can be defined as follows: "The pharmaceutical industry itself is defined as comprising bulk drugs […] as well as over-the-counter preparations for the use in human health care." (Redwood, 1987, p. 1). Over-the-counter preparations are drugs obtainable without prescription. Further, the pharmaceutical industry is high-selling. For example, the worldwide sales covered 962 bn USD in 2012, and should reach 1.200 bn USD in 2016 (Institute of Healthcare Informatics, 2012).

Because of numerous actors, the pharmaceutical supply chain is characterized by a high complexity. Figure 2.1 gives an overview about the essential actors within the supply chain (Abramovici et al., 2010). It should be noted that figure 2.1 focuses on the pharmaceutical industry in Germany. Nevertheless, this overview should support the understanding of the ongoing research process to identify transparency improvements (see 4.1.). Due to complexity, the research project focused on the red drawn line which represents the common process in drug supply.

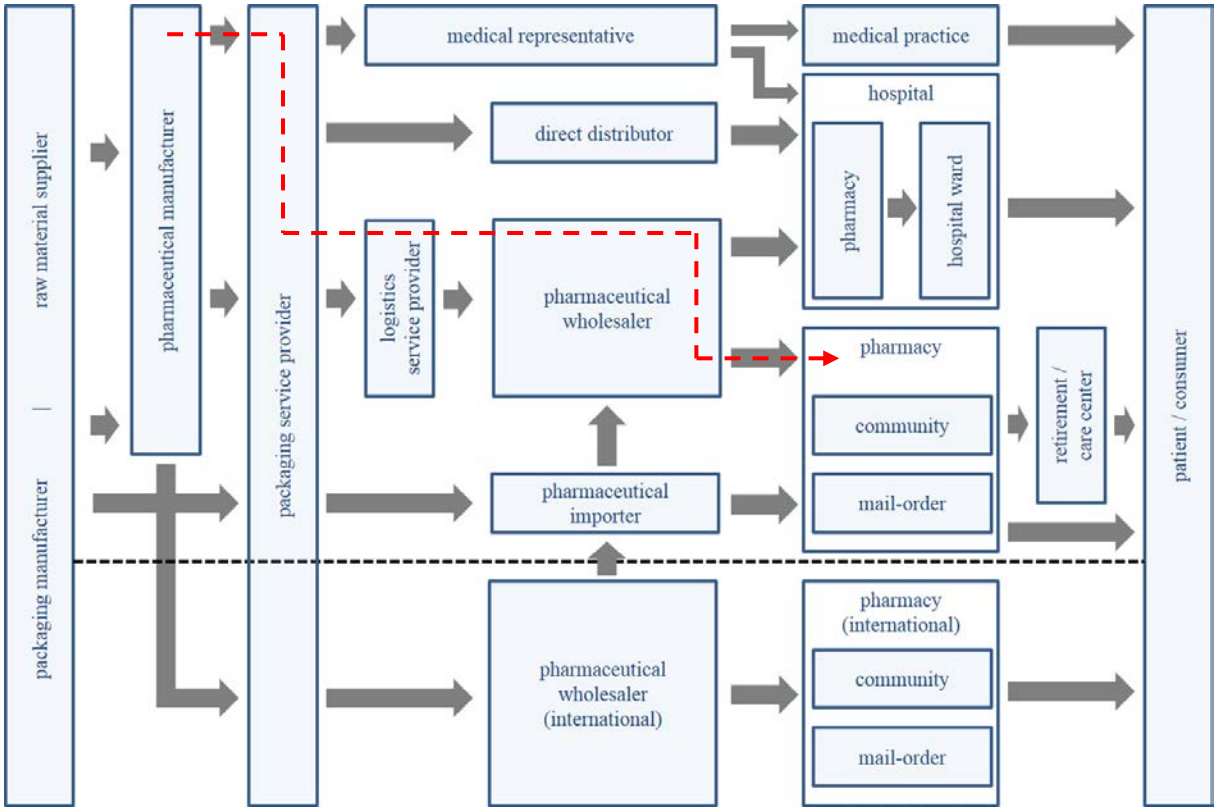


Figure 2.1 actors in the pharmaceutical supply chain

As this figure implies, all drugs which are needed in domestic community pharmacies pass the pharmaceutical wholesaler. A direct supply from the pharmaceutical manufacturer occurs only in very rare cases, e.g. drugs with a short durability. The supply of wholesalers with drugs from the pharmaceutical manufacturers or packaging service providers is carried out by logistics service providers. The service portfolio of logistics service providers embraces transportation, storing, and value-added services, e.g. customer-related finishing. Besides, the transportation of drugs can also be conducted by transportation service providers. These providers focus on temperate carriages and can represent the grey arrows between the actors of the supply chain. Further, it should be mentioned that there do not exist any rules which regulate the supply of the pharmaceutical wholesalers. Consequently, these wholesalers can re-import drugs by

imports from international pharmaceutical wholesalers. Finally, the consumer or patient can buy drugs from national and international community- and mail-order pharmacies. Besides, he can also receive drugs from hospitals, care centers, and medical practices.

2.2.2. Challenges in the pharmaceutical supply chain

With regard to the meaning of pharmaceutical products for human-beings and occurred drug disasters, controlling institutes such as the European Medicines Agency (EMA) in Europe and the Food and Drug Administration (FDA) in the USA were established. Following on this, they issue strict regulations. These strict regulations in terms of transparency for manufacturing and distribution constitute enormous challenges for SCM in the pharmaceutical industry (Beeny, 2008; Emond, 2008). With regard to the new GDP guideline (Spiggelkötter, 2013), interpretation difficulties do not lead to rigorous concept development in all supply chain entities. Against the background of financial reasons, the actors pursue risk-oriented concepts which do not ensure a complete guideline implementation. Thus, the overall aim of patient safety will be not achieved. To achieve this and to prove the adherence of the requirements, the continuous recording of temperature information has to be assured along the whole distribution. This, in turn, leads to increasing transportation costs and a need for an intensive information processing. Aggravating this situation, the supply chain is characterized by a frequent change of vehicles and many interfaces which cause a need for a wireless temperature recording to maintain an expected distribution pace.

Due to the use of different vehicles and interfaces, the actors of the pharmaceutical supply chain are faced with the challenge of process complexity. This situation leads to non-transparency and raises the threat of counterfeit medicine which can be smuggled into the supply chain. In addition, incorrect deliveries can cause enormous costs due to drug sensibility and value. Following on this, occurred recalls of charges can lead to high expenditures due to non-transparency within the distribution process. Viewed from this perspective, a disturbance of the crucial synchronisation of information- and material-flow within the chain can be recognized.

2.2.3. Current approaches for SCV in the pharmaceutical supply chain

Regarding the aforementioned challenges, two essential problems can be recognized. The first problem deals with the temperature topic and its recording. The second problem concerns the difficult synchronization of information- and material-flow. For these reasons, this section gives a short overview about current solution approaches to increase SCV.

In terms of temperature monitoring, data-loggers are often used in the pharmaceutical supply chain (see e.g. DHL Smartsensor, 2015). Data-loggers are small objects which meter temperature profiles. In that context, two types can be distinguished. The first type only indicates temperature transgression or lower deviation by a color indicator. The second type allows a continuous temperature recording. Therefore, an integrated sensor captures temperature data in defined intervals and saves these data in the data-loggers memory. The data-loggers are then put into the transportation accessories of the drugs to monitor temperature profiles. The reading process of the loggers can be conducted by the receiver itself, or by the consigner with a respective return of the logger back to the consigner.

The aforementioned data-logger observes temperature profiles, but he does not preserve the drugs against too high or too low ambient temperatures. For that reason, data-loggers are used in combination with active or passive temperate shipping units. These units are equipped with cooling elements to keep defined temperature levels for a certain interval. Besides, temperate envirotainers with data-loggers in form of unit load devices allow global air freight deliveries within the pharmaceutical supply chain.

In order to pursue deliveries with a track&trace system along the whole supply chain, the deliveries have to be identified. Here, the pharmaceutical industry uses the barcode to identify, control, and track their drugs (Hansen and Gillert, 2008). But against the background of its limited information density, the barcode can't prevent the entering of product counterfeits. Thus, the pharmaceutical industry forces the use of the data matrix code. This code allows identification processes on product level and therefore provides much more transparency within the supply chain.

An associated application of the data matrix code is securPharm. This system should allow verification of authenticity of each medicine product (securPharm, 2014). Detailed information about verification, data storage and retrieval, and revenue mechanism can be found in the reference. The labeling of the medicine takes place with a data matrix code (standardized ISO coding) to ensure a global and unique readability. The code consists of a product number, charge number, expiration date, and an unique serial number. With regard to the verification process, the data matrix code will be printed on the product packaging. Besides, the code is stored in a central database of all participating product manufacturers. Following on, the code is copied on a second database which is only accessible by pharmacies and wholesalers. Then, wholesalers as a connector between manufacturers and pharmacies can conduct a verification of authenticity of the product packaging by a scan process. Furthermore, the druggist itself can conduct a further verification process. This is done by a scanning process and a data matching with the pharmacies' database.

3. Research Methodology

To answer our research question, a suitable methodology had to be chosen. The research question focus on the identification of SCV improvements by Auto-ID technologies. This requires a detailed understanding of the existing processes in the supply chain. Hence, a qualitative methodology is more appropriate because it allows a detailed information gathering (Harding, 2013). Due to the character of our research question, the case study methodology was chosen to answer this type of question. This methodology is primarily addressed by Eisenhardt (1989) and Yin (2014).

A first important part in conducting this methodology is the preparation and design of the research case (Yin, 2014). Regarding our research focus, an embedded multiple case design was selected. The pharmaceutical industry forms the coherent context of this multiple case design. Consequently, different companies from this industry were selected and represent suitable cases for the investigation, whereas their supply chain processes and transparency activities are the unit of analysis. Table 1 gives an overview about the case study partners. The case studies were conducted from winter 2013 till spring 2014. During the investigation, several sources, e.g. interviews, documents, and firm visits, supported a comprehensive case study analysis. These sources should also support data triangulation for research validity, and an analysis of the problem from different perspectives. Here, several expert interviews at different supply chain entities were conducted. These interviews supported the extraction of detailed information about the field of interest from experienced practitioners (Gläser and Laudel, 2009). Additionally, documentations about SCV in the pharmaceutical industry endorsed the research process as well.

Further and in terms of a structured research process, the authors employed a structured interview guideline to enable a complete and comparable information inquiry along the supply chain process (research reliability). Before conducting the interviews, the interview guideline was pre-tested in terms of comprehensiveness, complexity, and interview duration. Finally, all interviews were audio recorded to create interview transcripts and to support case analysis.

The data analysis was conducted with regard to time series analysis, especially chronological sequences (Yin, 2014) to identify reasons for insufficient SCV, and accordingly points for improvement possibilities by AutoID-technologies. In this sense, the insights from the multiple case studies lead to a process model (figure 4.1) which shows the coherences of the supply chain processes and actors. In combination with the identification of information points for enhanced transparency, the functional performance profile of the current approaches was mapped (see e.g. Prockl and Pflaum, 2012) to visualize improvement possibilities. Moreover, a (market) analysis supported the selection of suitable technologies. Following on this, a target process with improvement recommendations was devised. Therefore, the next chapter presents our results.

Table 3.1 Overview about case study partners

Case	Actor in the supply chain	Employees (2013)	Revenue (2013)
1	Drug producer	< 250	> 1.000 MEUR
2	Transportation service provider for wholesalers and pharmacies	< 250	> 1 MEUR
3	Logistics service provider	> 1.000	> 100 MEUR
4	Drug producer	> 50.000	> 10.000 MEUR
5	Drug producer	> 10.000	> 10.000 MEUR
6	Logistics service provider	< 250	> 1 MEUR
7	Logistics service provider	> 1.000	> 1 MEUR
8	Pharmacy	< 250	> 1 MEUR
9	Pharmacy	< 250	> 1 MEUR
10	Wholesaler	> 1.000	> 1.000 MEUR

4. Analysis and Results

The insights gained from the case studies about the individual process steps in the supply chain are combined in a cross-company process model (figure 4.1) to identify unused potentials for transparency improvement, and further process optimization needs. To highlight security transitions and interfaces, the actors in the process model were divided in swimlanes. As mentioned above, the authors focused on a special path within the supply chain (see figure 2.1). For simplification purposes of this paper, no packaging service provider is taken into account throughout the modeling process. This, however, does not affect the results of the holistic approach because of the possible integration of packaging service into the upstream value creation stage. In terms of enhancing SCV, identification points have to be identified along the supply chain. Within the processes of the different actors, many points could be identified at which information is gathered for cross company or internal purposes. Some of these processes are already fully automated, or supported by appropriate technologies. Others still function without any technical support at all. But in order to provide supply chain visibility, process automation is mandatory. In general, the potentials for improvements will result from technical support or automation, e.g. time savings, synchronization of material- and information-flows. Therefore, 4.1. begins with the presentation of our analysis in terms of improvement points. Based on this, derived SCV improvement approaches are explained in subchapters 4.2. to 4.4.

4.1. Identification of improvements points within the supply chain

Present potentials in the pharmaceutical supply chain do not focus solely on one actor, but include all of the value-adding supply chain actors. At the manufacturing stage (see 4.1, diagram 1), several potentials within the process steps can be identified. For example the optimization of the temperature checks or the loading processes of incoming trucks, including the manual cargo controls. Both tasks are very time consuming and could be accelerated by increased automation. In addition, automation would also result in higher process transparency. Especially the loading process could be enhanced through technological support by reducing the risk of failures, e.g. incorrect loading sequences.

At the following stage of the value chain, a transportation service provider runs the consignments through various process steps, which comprise several potentials for improvement (see 4.1, diagram 1, 2). The process analysis revealed that the consignments have to pass many identification points. This is also very time-consuming because of the extensive numbers of item scans, decreasing the performance of the whole supply chain. Moreover, it is not guaranteed that the consignments reach the correct transport vehicle for further transportation, even they have been scanned. Therefore, automatic identification throughout the entire process stage would lead to time savings.

Considering the whole supply chain, most potentials for improvements are identified at the level of logistics service providers (figure 4.1). For instance, enormous time savings can be achieved by communicating temperature data of goods in advance. If a deviation of the transport temperature is communicated in advance, an early request can be send to the manufacturer to reassess the product's quality before its actual delivery. Another process step with enormous potential to optimize process accuracy and speed is the check of batches, and the scope of delivery. This is currently conducted manually and randomly. Automatic identification of each package could replace these random checks, thereby reducing the risks of failure, and minimizing process time. In addition, there are several other potentials imbedded in the processes of picking and shipping goods. At present, containers are weighed to ensure order completeness and correctness. But this method contains a certain degree of inaccuracy due to similar weights of different products. Even more concerning is the fact that no review of the batch or the expiration date of the picked goods is conducted. All these issues can be solved by an automatic identification system using an electronic tag on each package.

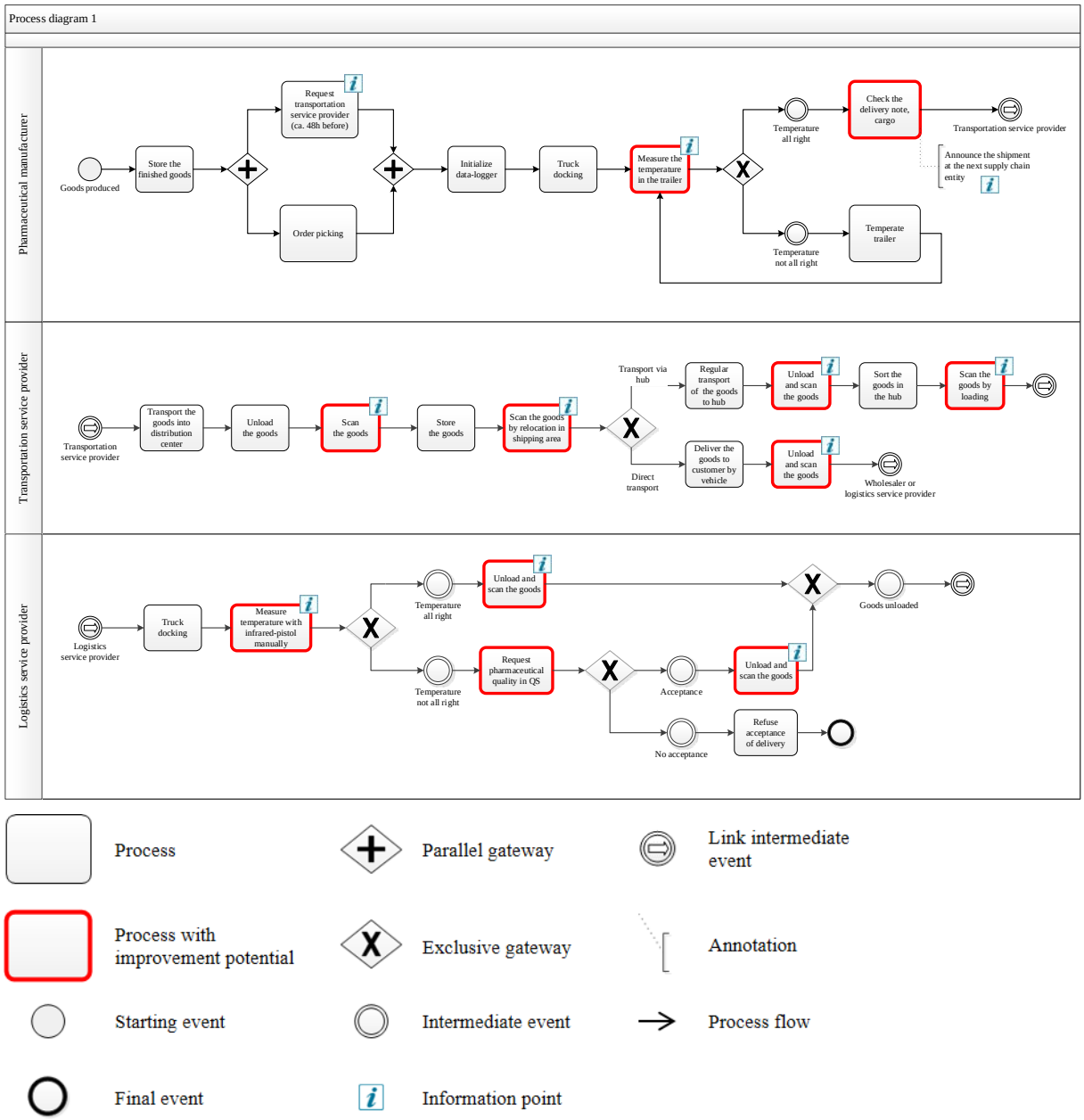
In the goods issuing department (see 4.1, diagram 3), potentials for improvement exist in the area of consignment consolidation, and in the interim storage process. In the consolidation area, individual packages are packed together on a pallet. In the interim storage process, goods are stored right before they are handed over to the transportation service provider. In both steps, the risk of misclassification of the items is present, e.g. a package is placed on the wrong pallet, or a pallet is parked into a wrong temporary storage space. In this context, improvement potentials for process reliability are identified.

Opportunities for transparency improvement and time also exist in the process flow of the pharmaceutical wholesaler (see 4.1, diagram 2). Here, the content announcement of combined incoming shipments, the check for completeness, and the storage of goods is done manually. Obviously, this leads to errors in the picking process and in the consolidation to delivery tours. Hence, an electronic dispatch advice with a radio-based automatic identification system on product-level can support in terms of time, process quality, and reliability.

The last process steps include the transportation of the goods from the pharmaceutical wholesaler to the pharmacy, and the processes within the pharmacy itself (see 4.1, diagram 3). Based on the analysis, these steps contain only a few potentials for enhanced transparency. Here, there is only one very crucial element, which holds significant potential for improvement:

automatic logging. Currently, the transportation service provider of the wholesaler records the delivery of goods only in exceptional cases, e.g. anesthetics. Therefore, no information tracking is possible between the time handing goods to the transportation service provider and the end of the transport. An automatic logging and an unique identification of the goods at the beginning of the transport would access this potential.

Regarding the identified opportunities within the supply chain, it becomes evident that the currently applied approaches with their limited performance specifications, particularly a required combination in networking, large data storage, and unique identification, are unable to access the improvement potentials. Therefore, the following subchapters present three recommendations for accessing the potentials. These advices were derived from the case study insights, under consideration of the author's competencies in Auto-ID technologies.



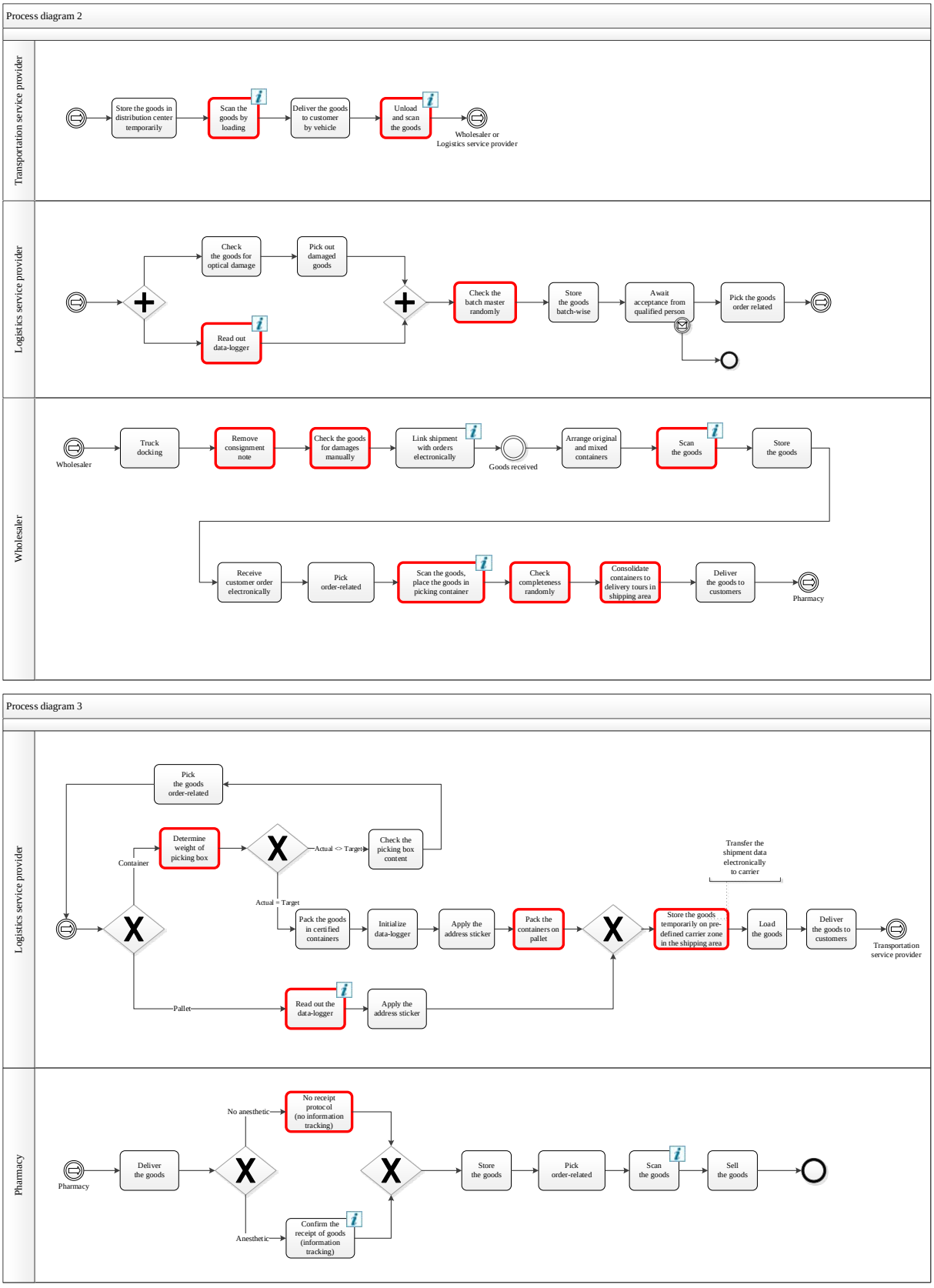


Figure 4.1 Process model with legend

4.2. securPharm with passive RFID tags for enhanced SCV

Because of the identified potentials in the areas of truck loading, delivery tracking, batch checking, and the documentation of the process flow, the implementation of the securPharm concept with small adjustments is recommended (figure 4.2). Although securPharm is still in the pilot phase, this approach would lead to higher transparency, security, and speed of the pharmaceutical supply chain processes. Furthermore, the legal guidelines with the respective needs of the actors and consumers force this approach.

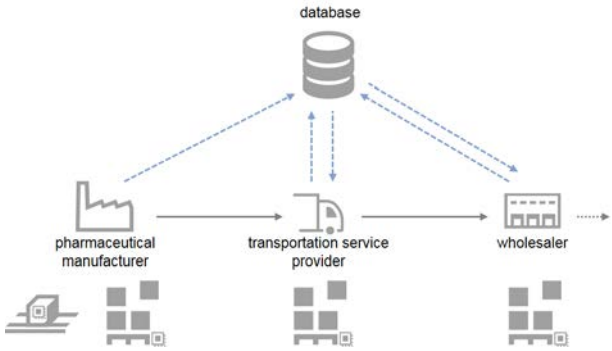


Figure 4.2 securPharm with passive RFID tags

For this, the basic concept of securPharm is used. But a passive RFID tag (Finkenzeller, 2010) replaces the printed data matrix code. The reason for this change is the increasing capability of today´s technologies to save much information directly on item-level, and throughout the entire process. For example, information about the temperature profile of the drugs at each supply chain stage is logged on the rewritable RFID tag before the goods are handed over to the next stage. So, the drugs themselves act as an information carrier. In addition, the information can be uploaded by a scan activity and compared with already existing data, supplementing already existing information in the central database. Hence, fluctuations in product temperature during the transportation can already be seen in the central database before a delivery. So, further decisions about the ongoing procedure can be made in advance. Consequently, the expansion of the securPharm concept from packages with a data matrix code to a RFID tag fulfills the requirements of a higher degree of security and transparency by an exact knowledge about temperature profiles and process history.

Moreover, this advice meets the requirements for efficient processes due to automatic and contactless identification on item-level, and decreases process times. To implement the securPharm approach, existing structures and processes must be modified or changed. Besides, new packaging with integrated RFID tags and RFID readers are necessary at all supply chain stages. Furthermore, software-related adjustments and appropriate middleware systems are needed to enable a continuous cross-company implementation.

4.3. Transport container with sensor nodes for enhanced SCV

Currently, the authors do not see a launched technological solution on the market, which is able to monitor the drug package temperature accurately in the fine distribution, and assign transport containers correctly to each delivery. Therefore, one way to counteract the present black box is the equipment of transport containers from the pharmaceutical wholesalers with sensor nodes (figure 4.3). The nodes accompany the containers through the whole process and store information. Sensor nodes are small computer tags capable of detecting the environment, data storage and processing, and communicating with other nodes or a database (Zheng and

Jamalipour, 2009). The nodes can build a sensor network with redundant communication paths. The containers are linked with a pharmacy order and the corresponding delivery at the beginning of a picking process. During a picking process, all available information about the drug, previous transportations, and the part number are stored on a sensor node. This allows a high level of transparency, by an unique assignment of products to each individual transport container.

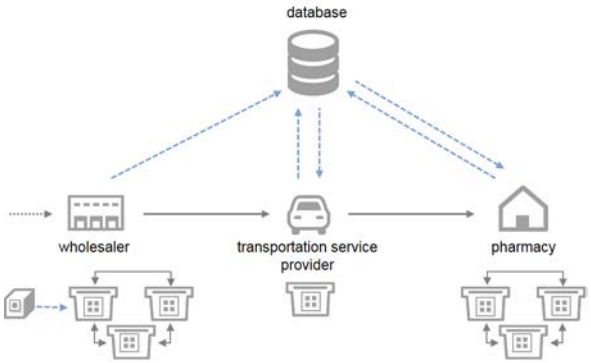


Figure 4.3 Transport containers with sensor nodes

When goods are issued for delivery, incorrect tour assignments can be prevented by the use of sensor nodes through their redundant communication abilities. Furthermore, the sensors generate an alarm signal, if the transport container is assigned to a wrong delivery. Inside the delivery vehicle, the sensor nodes connect themselves to a gateway, for communicating temperature data in predefined intervals. This information can be transmitted with a current GPS data to a central database. Here, it can be compared with particular product specifications. Additionally, if the temperature inside the transport container exceeds or falls below a predefined temperature, the sensor nodes send an alarm signal to the driver and further to the central database. Thus, even at this supply chain step, process transparency is preserved, and the black box in the fine distribution is eliminated. Once the transport containers are unloaded from the vehicle, the nodes can recognize this activity and forward the information, including a timestamp, to the database. In the pharmacy itself, the delivered containers can be read out, and the delivery status can be set to “delivered” in the database. The product information is then updated automatically within the central database.

4.4. Supply Chain Visibility Dashboard for enhanced SCV

The last proposal deals with a Supply Chain Visibility Dashboard (figure 4.4). Such a dashboard, available across companies, would make it possible to observe all processes and their current status at any time. The reason why this recommendation is helpful, is the fact that all data assessment is performed by separate IT systems with optical identification technologies, instead of one system across companies. Because of this separation, a comprehensive and continuous evaluation of the information is not possible, impeding the creation of process transparency. A centralized solution which includes all information about the supply chain creates visibility for all actors. To achieve the objective of such a cross-company system, a Supply Chain Visibility dashboard should consist of a web-based data center that is operated by a third party. This allows all supply chain actors an access to the dashboard, without a direct access to an in-house IT-structure of one of the involved supply chain actors.

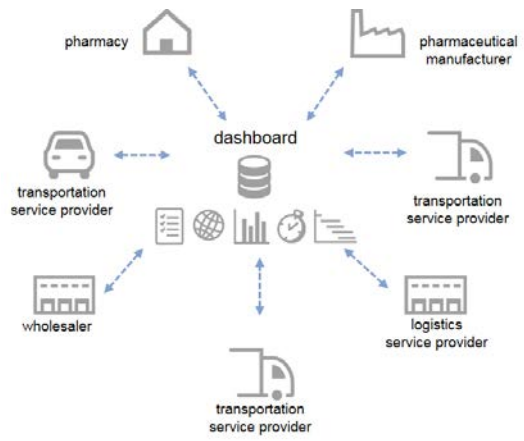


Figure 4.4 Supply chain visibility dashboard

A web-based dashboard uses the information of a central database, and prepares these information visually for all actors within the supply chain. An important factor to implement such a system is to ensure all parties only access to relevant information. The actors within the supply chain act as senders and receivers, with predefined access permissions. These senders and receivers can request information, such as temperature profile, delivery date, or delivery content at an early stage of the process. Thereby, supply chain processes can be accelerated. In addition, process transparency across companies enables the development of proactive actions in the form of escalation management. For instance, in case of a temperature deviation, it is possible to intervene at a much earlier stage, and to modify or change the following process steps. This proactive behavior optimizes controlling and the overall performance of the supply chain.

It should be mentioned that implementation time and economic feasibility are the smallest obstacles for a SCV dashboard. There are vendors for web-based logistics portals on the market which are able to quickly adjust such systems at low costs, under consideration of all requirements of the pharmaceutical industry.

5. CONCLUSION AND IMPLICATIONS

Based on the case study insights, the authors can only give a first prioritization of the recommendations mentioned above.

The implementation of the securPharm approach with passive RFID tags will lead to high complexity and extensive investments. This will result in a strong intervention into existing processes and infrastructures. These adjustments require a difficult payback period calculation due to the quantification of long-term and temporarily unknown benefits. So, further detailed assessments are necessary to define a respective business case.

By implementing the sensor nodes recommendation, the previously opaque processes within the chain will become more transparent. Additionally, the overall aim of patient safety will be complied in a better way. From our perspective, the costs for the necessary investments within a closed system will be manageable and decrease over time, due to upcoming technological innovations (see e.g. Sahingoz, 2013). Consequently, this recommendation is assigned by a high priority, also against the background of encouraging experiences within other industries, e.g. the food industry (see Hafliðason et al., 2012).

From our point of view, the implementation of a Supply Chain Visibility dashboard holds enormous potential for improvements. Furthermore, this can be exploited with moderate costs due to existing firms which offer required platforms. The main advantage of this approach is that the central database of the securPharm approach can be used, even when securPharm is not realized. Here, the ongoing securPharm initiative in Germany can facilitate this recommendation. In this context, the platform architecture of EPCglobal (GS1, 2015) for unique product identification across companies provides a good example for decision makers to drive this recommendation. Therefore, the SCV dashboard recommendation is rated with the highest priority and should be implemented as soon as possible.

In sum, this work improves the comprehension of SCV for the pharmaceutical industry and emphasizes its significance. Legislative guidelines constitute enormous challenges for companies, whereby SCV gets even more important to satisfy these regulations and to guarantee best medicine quality.

Further, the paper shows present approaches for SCV and their deficits. Based on a broad case study, recommendations for enhanced SCV were identified within the pharmaceutical supply chain. These recommendations cover a securPharm approach with passive RFID tags, transport containers with sensor nodes, and a SCV dashboard. The use of these recommendations can lead to optimized interfaces, higher transparency, and thereby to shorter process-times within the supply chain. Therefore, the related decrease in process costs and the increase in data quality add substantial value to each supply chain actor. So, this study enlarges the research body about SCV and SCM, especially in terms of our underlying SCM definition perspective to enhance customer value (Christopher, 2011). In particular, the accuracy and granularity of the generated data allows a continuous monitoring of the supply chain performance which plays an important role in the pharmaceutical industry, due to high quality standards. Further, the recommendations can help to improve the visibility of orders which is crucial for competitive aspects (Holcomb et al., 2011). Finally, the developed process model serves as a checklist or analytical framework for further research or practical investigations, continuing the important cold chain research (see Emond, 2008).

However, our study has some limitations. Due to the complexity, the analysis focused on one path within the pharmaceutical supply chain. So, a transmission of the recommendations to other paths has to be done carefully. Next, our study has a regional focus on Germany. Nevertheless, the legislative guidelines are at least valid for whole Europe. Finally, SCV is a broad research area. Here, the authors focused on a process perspective and on Auto-ID technologies. Hence, the identified recommendations do not claim for completeness.

Thus, further research can investigate the implementation costs of the recommendations in more detail. Furthermore, a precise comparison of the recommendations based on cross-company criteria can be conducted. Also other paths within the pharmaceutical supply chain have to be analyzed in terms of SCV improvements. Here, insights can be coordinated with each other to generate further synergy effects. Another interesting research proposition is the connection of SCV improvements with supply chain performance or key performance indices. Regarding the SCV dashboard, possible incentives for information exchange between the actors have to be investigated because the exchange of partly sensitive information is always critical. Here, maybe community approaches can help. Finally, analysis in other countries can lead to different interesting approaches for enhancing SCV within the pharmaceutical supply chain.

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A framework for supplier innovation:
Implementing structures in purchasing for detecting and applying supplier innovation capabilities

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ABSTRACT

Purpose
The purpose of this paper is to explore structures and activities in purchasing management to detect capable suppliers with innovation potential. The intention is to define structural elements for strategic identification of external innovation capabilities. This approach should assure a more appropriate fulfilment of diverse operational demands and should support valuable processing in supplier innovation practices.

Design/methodology/approach
The selected applied research builds on a literature review on supplier innovation management. A data analysis for identifying strategic suppliers based on company's data followed by a distinctive qualitative case research with 34 focus group interviews at the purchasing management level. The identified aspects from the literature serve as a means of comparing data with the recorded statements from the interviews.

Findings
While the management of innovation processes is strongly dependent on how network partners cooperate, limited research has been done particularly within companies' purchasing. In this case, the strategic focus in purchasing is of major importance. Here, identified characteristics and implications of innovative suppliers in this applied case allow a responsive environment to capture inventive ideas and developments for purchasing managers.

Research limitations/implications
The literature review is of a selective character and the qualitative analysis within limited fields as the underlying project initiative is exploratory and tailored to company-specific prerequisites.

Practical implications
The findings illustrate how a structured framework for innovation management in purchasing can be designed decisively within a company-specific approach.

Original/value
Research approaches which consider the role of supplier capabilities in innovation as important rarely refer to "purchasing" as being a company-specific innovation enabler.

Keywords: Innovation, supplier innovation, purchasing management, supplier involvement, innovation strategy

1. INTRODUCTION

Innovation is an essential business dynamic for survival and success of companies and a highly accepted issue in modern entrepreneurial thinking and behavior. Indeed, companies operate in their respective markets with the conviction that if they cannot launch new ideas, initiate changes and improvements in their work, products or services, then sooner or later other competitors will, provoking changes in their own competitive position and that of others. It is then the case that know-how and experience for innovating products, processes or services becomes a key capability (Charterina and Landeta, 2010).

In today's business environments, innovation no longer occurs in one single organization. It exists within the multiple links along the value chain between involved companies, their suppliers and even customers. The major challenges of successful innovation processes thus lie in scanning the organizational context for interaction ability, technical and managerial knowledge (on the supply as well as on demand side), assimilating this into one focal organization and combining it with existing internal knowledge and capabilities. The idea that innovation is an interactive process suggests that well-selected relationships in the innovation process are required. It is assumed that the exchange of knowledge, the intensive interactions between specific actors (personal and inter-organizational) and the joining of forces within networks are important elements in engaging cooperative innovation dynamics (Toedtling *et al.*, 2009). Aside from international, regional and inter-organizational levels, the organizational structures of the focal company strongly influence ability and capability of innovative activities. As continuously changing external conditions require innovative development, flexible structures in the respective organization provide an effective basis for that issue (Preuss, 2007). With this view along the overall supply and value chain, the organizational function of purchasing in industrial companies is of high importance. Purchasing in its specific role is concerned with the acquisition of materials, components and with the crucial partner selection for ensuring high-quality processes. Referring to this task of managing incoming resources (materials, services, equipment, etc.), the corporate purchasing function is considered to be in a prime position to decide, initiate and foster innovations among the various value chain members (New *et al.*, 2000; Preuss, 2007).

Referring to the aim of the present paper, the focus hereby is on supplier innovation in which purchasing acts as a key driver for generating promising preconditions for detecting and applying supplier innovation capabilities. The purpose is to define framework elements for strategic identification of external innovative competences and should support valuable processing in supplier innovation practices – based on the underlying and investigated focal company.

The importance of purchasing strategies and operations within the company investigated has risen sharply in recent years, as is the case in many other companies. Four years ago, a binding set of rules, called the "purchasing manual" to support (i) the divisional purchasing process (across subsidiaries and business units towards the central purchasing department) and (ii) the strategic sourcing activities (learning phases for purchasing personnel) was agreed. In order to enable the central purchasing department to perform specific strategic activities, operational tasks were reduced to a minimum. This step was achieved through a radical change of the purchasing process through an improved use of existing and developed IT-systems and cross-divisional interfaces.

According to the defined conditions (e.g. purchasing manual, implemented IT-interfaces and strategic procurement development), all internal customers (i.e. subsidiaries and business

units within the group's divisions) are committed to an early integration of the purchasing department. This promising approach ensures that purchasing/procurement strategies are coordinated between technical and purchasing functions. A successful basis in purchasing is established at this early stage of the decision-making process. The future of the company enfolds a vision of a purchasing-network-character, (i) acting in cross-functional teams, (ii) as a reliable partner on equal terms with supplier partners, and (iii) developing and implementing supplier innovations. This vision targets an efficient cooperation with innovative supplier partners to provide higher, sustainable value contributions.

Referring to the stated vision of the company investigated, the current innovation potential of suppliers is far greater than currently used. In order to enrich the potential to be used and implemented in the future, there is a need for several aspects that justify this applied research: (i) recognizing innovation performance suppliers, (ii) creating opportunities for the introduction of supplier innovations, (iii) selecting the most promising innovative ideas, and (iv) elaborating efficient and effective ways of working and methods for their implementation.

2. LITERATURE REVIEW

The growing importance of innovation to company's business operations is reflected in a dramatic increase in the literature that addresses the role and nature of innovation (Drucker, 1985; Drazin and Schoonhoven, 1996; Johannessen *et al.*, 2001). For the concept of innovation, there is a variety of definitions to be found in the literature. In the original definition it is about novelty and newness. There the perception of newness is essential to the concept of innovation as it serves to differentiate innovation from change (Slappendel, 1996; Johannessen *et al.*, 2001). When exploring different types and directions of innovation, the characteristic of *new* is not just limited to products but also applies to new processes, procedures, services or business models. But not only does novelty signal an innovation, but ultimately the implementation and thus the practical application of something new. Innovations lead to a special means-purpose relationship. Therefore a new innovation is an offer (means) which fulfills a purpose in the case of appropriate demand (Haunschild and Salomo, 2011).

The literature also describes innovation related to cooperation and networks but without a substantial valid relationship (Fritsch, 2001). On the one hand, (i) innovation practices require cooperation due to exceptional resource intensity in processing and because of (ii) needed complementary knowledge that can rather be gathered through long-lasting relationships and efficient networking. On the other hand, innovation practices are seen as being stimulated through valuable relationships and cooperating networks. This captured literature view designates innovation as an interrelated process with a cooperation and network character (Toedtling *et al.*, 2009). Innovations represent the perspective of new orientations and offer the opportunity for growth and long-term continuance of companies. The role of innovation in enhancing competitive advantage is central to the concept of differentiation strategy (Porter, 1985), and the impact of innovation on business performance has been demonstrated in a number of studies in innovation research (Subramanian and Nilakanta, 1996; Prajogo *et al.*, 2004). Innovations offer the chance to set an example for evolution in business. Innovations require no internal revolution in the company but an elaborate building up of a solid management process and an organization that allows new ideas and promotes their implementation. For the present case and with regard to the paper's aim, a wider perception of the term innovation is considered. Approaching the view of Schiele (2006) and Haunschild

(2004), innovation refers to *something new to the focal company* – regardless of the specific type of innovation (e.g. a new process, a product innovation, etc.) – and related to a probable support/cooperation with a supplier partner (Haunschild, 2004; Schiele, 2006). As previously mentioned, the role of capable network partners (for exchanging and developing ideas) within a fruitful innovation framework is vital.

In this context, innovation management practices are as vital as sourcing strategies. By evaluating and finally selecting suppliers the purchasing function has a strong influence on a company's innovation performance. Selected suppliers may contribute to a company's innovation by performing research & development of its own and thus absorbing some expenses the focal company would normally have to incur. Moreover, suppliers may have valuable knowledge of production and fulfillment processes that may influence the focal company's performance. As suppliers can transfer ideas for products or processes to their partners, a partner within the supply network is enabled to enhance new products and/or processes for itself or in cooperation with others (Corsten and Felde, 2005). When incorporating supplier partners, Krajlic (1983) proposed a purchasing portfolio approach in order to distinguish the management of suppliers with innovation potential. Therefore, the role of the purchasing function results in ranking supplier partners according to their importance for the focal company (i.e. classified supplier value contribution) or their level of complexity or quality of products/services (Krajlic, 1983; Rosell *et al.*, 2011). This emphasizes a strategic innovation management step reflecting both the efficiency and performance of strategic activities to develop products or process under the high focus of novelty (OECD eurostat Oslo Manual, 2005; Rosell *et al.*, 2011).

2.1. Achieving success in innovation management

Due to the volatile markets and continuously increasing change cycles, it is a significant issue for every company and involved employees to be actively concerned with the creation and implementation of new ideas and thus generate innovation. The necessary central core tasks, to make innovative decisions and to realize implementation are embedded in innovation management. Innovation management designs the processes and systems, and provides the strategic structure to enable the implementation of innovations (Haunschild and Salomo, 2011). To precisely define this management task, Meffert et al. (2008) provide a detailed innovation management structure according to which the authors divide the innovation process into both strategic and operational sections. In the phase of strategic innovation, strategic decisions in terms of (i) alignment, (ii) necessity, (iii) source, (iv) organization and (v) use are set. In the phase of operational innovation, the process of implementation (from creating ideas to application) is managed (Meffert *et al.*, 2008).

Innovation management requires an integrated process and must be part of the corporate strategy. For successful implementation, the commitment of management and its communication is essential. A clear innovation management process sequence, guidelines and transparent decisions, can develop a company's innovation performance in the right direction (Stern and Jaberg, 2010). As there are a variety of approaches and methods in the innovation processes, Disselkamp (2012) puts it in a nutshell: It is not the naming or the detailed process stages that matter, but the fact that the process is recognized and is consistently followed as such (Disselkamp, 2012).

In addition to that process view of innovation, the structures of companies and their partner network along the value chain is significant. At the company level, size seems to be a good predictor of innovative activity. While some innovation occurs in small businesses, larger firms usually have greater financial resources and a broader access to more complex and

diverse resources and capabilities (Damanpour, 1992; Preuss, 2007). Furthermore, organizational structures can influence innovative activities. Flexible structures seem to offer a better basis for coping with changing conditions and high volatility than mechanistic control structures can achieve. That means that innovation no longer occurs in one organization alone. Managing innovation happens within networks, between firms and with the involvement of customers and supplier partners. The major challenges of successful innovation processes thus lies in scanning the organizational context for technical and managerial knowledge, assimilating this into the organization and combining it with existing internal knowledge and capabilities (Powell and Grodal, 2005; Preuss, 2007).

2.2. Innovation management in purchasing

While the management of innovation processes is strongly dependent on how network partners cooperate, the strategic focus in purchasing is of major importance because its activities are located at the interface to the suppliers. The matching of the external innovative capability of suppliers with internal innovation strength signifies for great potential in the purchasing framework. It is an important task in purchasing to select the right suppliers that can make a contribution to innovation in an effective manner (Schiele, 2006).

Wagner (2008) believes that innovation not only takes place in the individual company, but in cooperation with other companies as an interactive process. The suppliers thereby play an increasingly important role. As previously mentioned, the identification and use of supplier's potentials for innovation is becoming increasingly important when companies develop skills to identify, to support and to retain innovative partners in order to generate competitive advantage. The innovation potentials of suppliers are still widely underused. Many companies are only beginning to reconsider innovation aspects of their supplier partners (Wagner, 2008).

In order to identify capable suppliers in terms of innovation and cost potential, supplier evaluation systems need to be updated conceptually through additional factors e.g. future contributions and future requirements. It is a strategic purchasing task to develop that issue. In the first step of the evaluation process, the following innovation criteria can be considered: (i) innovation behavior and speed of innovation, (ii) technical/technological competitiveness, (iii) relationship to suppliers or (iv) "cultural fit". The second step involves the supplier actively, when selected criteria are evaluated from the suppliers' perspective. A closing joint workshop releases further possible potentials and enables development and implementation (Fuchs and Kaufmann, 2008). This example refers to the integrated character in innovation management on the one hand, and to the importance of the purchasing framework on the other.

As purchasing in industrial companies has been subject to significant changes in recent years it has evolved into an active and strategically decisive role with a hands-on character. The importance of purchasing continues to grow. Through expanding the purchasing framework with the innovation management function, an early involvement in the concept stage and development (relationship maintenance) is set.

2.3. Applying supplier innovation

The importance of relationships to trading partners within the partner or supply network highlights the role of customers and suppliers. While the customer-side relation is essential in understanding the market and fulfilling customer needs, the role of suppliers also determines innovation management performance in companies. In this research, the supplier-side is of central reflection as it refers to the vital purchasing range of functions. Among a number of key practices, supplier involvement in product development has attracted significant attention in the innovation literature (Bozdogan *et al.*, 1998; Handfield *et al.*, 1999; Ragatz *et al.*,1997).

From a strategic point of view, this means an opportunity to develop strategic alliances with capable suppliers aimed at enhancing organizational competitiveness through innovation (Prajogo *et al.*, 2004).

For a profound assessment, identified supplier innovation indicators from the literature (i.e. frequency of being mentioned) constitute an important basis for characterizing and differentiating aspects of innovative suppliers.

Table 1- Collected indicators characterizing innovative suppliers

Supplier innovation indicators	Main innovation characteristics & implications
Internal networking Relationship management Long-term cooperation Decision-making capability Early project involvement	Network capability The success of innovation correlates positively with the quality of cooperation and relationship level. Collaborative innovation developments integrate professional disciplines, reduce power imbalances and generate original value. (Handfield et al. 1999; Fischer, 2006; Schiele, 2006; Hauschild & Salomo, 2011)
Trust in interaction Information exchange Social competence	Social competence & communication Trust is a key factor in innovation cooperation. It reduces monitoring costs in the process of transferring tasks to partners, promotes conflict sensitivity and values dependence on partners as an opportunity rather than a disadvantage. Accurate communication skills and clear interaction (in both directions) represent essential prerequisites of an innovative supplier partner. (Ernst, 2002; Milberg & Schuh, 2002; Primo & Amundson, 2002; Fischer, 2006; Hauschild & Salomo, 2011; Schiele, 2006)
Management commitment Customer focus Targeting strategy Know-how protection	Strategic competence Proactive innovative companies are characterized by ambitious strategic goals and values that emphasize creativity and innovation. The responsible personnel are informed about customers' needs and strategic supplier goals. (Ernst 2002; Primo & Amundson, 2002; Fischer, 2006; Schiele, 2006; Hauschild & Salomo, 2011; Davila et al., 2013)
Personnel R&D resource and planning activities Company size	Resource management The creation of open and temporal space for research and development, the implementation of innovative ideas can be facilitated decisively. Innovative suppliers, e.g. through corresponding company size, must show this ability. (Milberg & Schuh, 2002; Fischer, 2006; Schiele, 2006; Kang & Kang, 2009; Schiele, 2012)
Specialization abilities (USP) Training program Reception and transfer of knowledge Technical & managerial know-how	Knowledge and learning Although experience (exchange), references, networking of knowledge and technical expertise are important: strong innovative suppliers are increasingly characterized by a high degree of specialization. (Primo & Amundson, 2002; Fischer, 2006; Schiele, 2006; Wagner, 2008, Kang & Kang, 2009; Berghman et al., 2012)
Incentive schemes Cooperation and culture of openness Composition of teams and responsibility Internationalization	Organizational settings and culture Openness (i.e. towards lively national & international cooperation), few bureaucratic regulations, interdisciplinary innovation teams and a positive error culture are important. If errors happen, learning processes and improvements can be promoted. (Ernst, 2002; Milberg & Schuh, 2002; Fischer, 2006; Wagner, 2008; Hauschild & Salomo, 2011; Disselkamp, 2012; Schiele, 2012; Davila et al., 2013)

The given indicators and implications on innovative characteristics of suppliers (Table 1) provide a vital contribution to the underlying applied company case. The need to identify contingencies on how structural applications effect supplier innovations, is readdressed in the following research elements. *A reconciliation of theoretical aspects of supplier innovation characteristics in daily purchasing management of the focal company* is explored in the case research, referring to issues of strategic purchasing initiatives.

3. APPLIED QUALITATIVE CASE RESEARCH

This applied research builds on the presented literature review on supplier innovation management (see chapter 2). A data analysis for identifying strategic suppliers based on the focal company's data followed by a distinctive qualitative case research approach with 34 focus group interviews at the purchasing management level. The identified aspects from the literature served as a means of comparing data with the recorded statements from the interviews.

Due to the previously mentioned strategic and organizational framework within the focal company, the purchasing department has an important role in detecting and applying innovation structures with active suppliers. With regard to the identification of strategic-fit and competitive suppliers the underlying research design gathered relevant implications and promising structures in this context. Table 2 displays the steps of an analytical approach (designed by the team of researchers) – from the initial research issue to the closing comparison of results and deduction of implications. An overview and a brief case description of each step of the research process are shown below.

Table 2 - Applied design research elements

Case research design element	Details and description
1. Research issue (based on the purpose and the literature review)	The *required structures in purchasing in order to detect and apply supplier innovation capabilities* are considered as the central research issue. *Several characteristics of high potential suppliers for innovation cooperation* are identified from the literature (see Table 1).
2. Analysis and segmentation	Data analysis of the existing supplier structure within the case company (3.978 active suppliers) and *segmentation* by supplier-source-portfolio. The segmentation shall lead to the *identification of strategic suppliers* that can potentially enter into innovation cooperation.
3. Qualitative focus interviews	The basic statements of *34 guided focus interviews with purchasing experts*, in condensed form, refer to the responses on each innovation indicator. Essential key messages support the respective main implications in each category.
4. Concentration of statements	A phase of *filtering statements* with the use of the innovation indicators structure was used to guide recorded empirical data for comparison with the respective aspects in the literature.
5. Comparison and deduction of propositions	The *similarities and discrepancies between the theoretical implications and empirical results* show a degree of overlap between the scope of findings in the course of detecting and applying supplier innovation capabilities.

The supplier *data analysis phase and differentiated segmentation of suppliers* (by means of supplier-source-portfolio analysis) allowed the derivation of strategic action, relevant for a specific share of suppliers.

When selecting the surveyed participants, a balanced mix of interviewees – differences in work experience in purchasing, age, educational level and company affiliation – were utilized for an application-oriented and broad empirical investigation process. The *focus interview phase*, conducted by the team of researchers, lasted 9 months until November 2014. The used interview guide included the indicators and implications – for detecting innovative suppliers – taken from table 1. In this context, the aim was to find out if participants' opinions are consistent with aspects derived from the literature, and what kind of experience regarding implementation of supplier innovation already exists within the company.

After the guided interview phase, participant feedback led to *concentration of statements* followed by a *comparison and deduction of propositions* to link theoretical aspects with refined practical issues.

4. IMPLICATIONS AND RESULTS

4.1. Supplier segmentation

On the basis of the identified research issue and collected indicators characterizing innovative suppliers (table 1), a data analysis for identifying strategic suppliers has been performed. An ABC-analysis by *order volume* was followed by a detailed qualitative consideration of all A-suppliers and a majority of B-suppliers, reviewed by the responsible purchasing managers. As for the *qualitative evaluation criteria* for potential suppliers, the following aspects were considered: (i) special technical expertise or process knowledge, (ii) important service partner, (iii) important back-to-back arrangements or (iv) already selected partner.

This segmentation resulted in *a selection of 109 strategic suppliers*, which represents a 2 % share of the total number of active suppliers. The segmentation described is of strategic importance when choosing innovative suppliers. It is essential to clarify the **strategic orientation within the respective purchasing segment** before stimulating innovation partnerships and projects. Thus the segmentation of suppliers is to be considered. How to proceed further with this initial supplier segmentation outcome is elaborated as follows:

Subsequently, the derived results refer to a threefold set of insights:

- indicators and conditions for recognizing innovative suppliers,
- previous experience in innovation projects (in terms of resources and evaluation of innovative ideas and approaches) and
- recommendations for the implementation of supplier innovations

from a strategic purchasing point of view.

In particular, it should again be emphasized that supplier segmentation plays an important role in the evaluation and selection of innovative suppliers, even more so under the criterion of **strategic orientation.** If strategic frameworks of projects are not resolved before the start of implementation, the "strategic fit" is not met. The **portfolio position of the supplier need to be identified** and issues such as **know-how protection, proprietary rights of use and exploitation** and **exclusive rights** need to be assessed at an early stage.

4.2. Innovation indicators and characteristics

In terms of highly promising indicators for recognizing innovative suppliers, the following propositions can be deducted.

The factor *"long-term cooperation"* (i.e. cooperation experience) is only rudimentarily confirmed by the interviewed participant, although, according to the literature, innovative suppliers are often involved in collaborative projects which represent an indicator of specific innovation resources and an open culture of innovation. Remarkably relevant in the investigated case, compared to the literature review, is *"know-how protection"*: from the interviewees' perspective know-how protection is of enormous importance. The empirical results showed an explicit cooperation requirement that regulates the suppliers to protect the know-how and intellectual property right of the innovation partner (i.e. the focal company). Aside from that, know-how in this particular consideration is mentioned but is under-represented in the relevant literature.

The indicators that support interdisciplinary activities, involvement, networking and trust (i.e. *"composition of teams and responsibility"; "early project involvement"; "internal networking/information exchange"; "trust in interaction"*) display the dedication to cooperation and significant network abilities that enable applied innovation practices. There are no clear clues among the investigated purchasing experts that "*R&D resource and planning activities*" significantly sustain the innovation potential of suppliers. A possible explanation for this fact is the centrally managed R&D activities – which happen separate from the group's companies – that were probably taken for granted here and not linked with supplier cooperation.

The most frequently mentioned indicators refer to *"reception and transfer of knowledge"*, *"decision-making capability"* and *"cooperation and openness culture"*, where the purchasing experts argued that companies with a specific focus on innovation take these as their key aspects. This view of innovation indicators favors a relational perspective in order to reap the benefits of innovative supplier partners. Table 3 displays the summary of registered responses with reference to the corresponding innovation indicators during the empirical phase.

Table 3 - Results of applied empirical research on supplier innovation characteristics

Supplier innovation indicators	No. of responses	*Innovation characteristics*
Internal networking	11	***Network capability***
Relationship management	9	
Long-term cooperation	8	
Decision-making capability	21	
Early project involvement	12	
Trust in interaction	14	***Social competence & communication***
Information exchange	14	
Social competence	8	
Management commitment	8	***Strategic competence***
Customer focus	10	
Targeting strategy	11	
Know-how protection	15	
Personnel	16	***Resource management***
R&D resource and planning activities	3	
Company size	14	

Specialization abilities (USP) Training program Reception and transfer of knowledge Technical & managerial know-how	6 7 22 10	***Knowledge and learning***
Incentive schemes Cooperation and culture of openness Composition of teams and responsibility Internationalization	5 18 10 5	***Organizational settings and culture***

4.3. Previous experience in innovation projects

In terms of previous experience in innovation projects, respondents were asked to comment ad hoc on initiated and processed innovation projects from the past. It is worth noting that the supplier was only once mentioned as an initiator. This confirms the current attitude that **suppliers are hardly used as an external source of innovation,** up to now. Tendencies towards **process innovations** were shown by responses to the type of innovation. This corresponds to the expectation, as the investigated purchasing department traditionally focuses on process optimization and development.

Some interviewees stressed the following statements on important criteria for processing and developing innovation projects: an existing **long-term cooperation and corresponding positive experiences** (alongside common business activities) with suppliers. Literally, the positive experiences were described by "a decent long-term cooperation and common history". In addition **clear objectives and strategic orientation on the suppliers' side** ensured the necessary clarity. This subsequently supported a smooth implementation process.

4.4. Recommendations for implementation innovations

The results of the focus interviews showed that **no explicit methods are used for implementation** of innovation projects within the company investigated.

In terms of application practices the success of an innovation depends profoundly on the design of the implementation, according to the case research results. The three main documented implementation perspectives are:

- interdisciplinary innovation teams,
- strong strategic involvement of suppliers and
- intense knowledge building and learning.

In addition, **willingness to change, trust, flexibility and the employees and management commitment** are recognized as key factors for the successful implementation of innovations. These aspects also have a strong influence on the interaction quality with supplier partners.

The additional value – created by joint interaction – and the acquired knowledge in particular need to be transferred into the organization's routine for sustained use. It is an obvious challenge to continuously maintain and develop **the circulatory system from (i) interpreting and understanding, (ii) integrating towards (iii) institutionalizing** innovative potentials.

According to the interview results, most of the projects are being **implemented without the integration of purchasing experts.** Involvement is done at a later time, when there is a need for functional support (i.e. additional purchases or in case of contractual protection). Therefore, strategic decisions and contractual agreements at the beginning of an innovation

project very frequently are neglected. According to the interview results, there was no evidence of a performed evaluation after the implementation of innovation projects. Hence, one may conclude that lessons learned from innovation projects are still not yet harnessed through a cross-functional transfer of knowledge and experience among relevant stakeholders.

It has been clearly recognized that the purchasing discipline will play a supporting role in innovation development of the focal company's future. A particularly conspicuous aspect is that business model innovation or service innovation have not been mentioned at this stage. These areas still have clear potential for future innovation efforts. The huge number of innovative projects that have been implemented up to now and supported by the purchasing department suggests that a lively culture towards development and improvement is present within the investigated company.

5. CONCLUSION

In a first consideration, the presented case is applicable to the involved case company, while findings could be further tested for applicability for the industry sector to draw more wide-ranging conclusions. Necessary structural elements in purchasing enable the focal company to have a more strongly focused supplier innovation management practice. The impact in purchasing operations, to detect capabilities and innovation potential on the suppliers' side, is condensed and designed for generating and evaluating supplier innovation.

As Schiele (2006) mentioned, the *strategic responsibility of the purchasing management* is of high importance when it comes to source and develop innovation. Matching external innovative capability of suppliers with internal innovation strength is decisive (Schiele, 2006). The segmentation process and the *supplier portfolio management task* (also stated by Rosell *et al.*, 2011) were identified as important from a purchasing point of view. According to the paper's purpose, the given results support the fact that a *strategic structure for supplier innovation should be of an integrated & interdisciplinary character* (as also stated by Fuchs and Kaufmann, 2008) and *upkeep decision-making capabilities* to put innovations into practice. In order to ensure an efficient and effective implementation of supplier innovations, the findings demonstrate an outline for an applied transfer into purchasing practice.

The successful implementation of supplier innovations at an operational level depends on the one hand, on the **quality of a structured innovation management practice** and on the other hand, on the **involvement and interaction of employees involved.** The innovation management process has a complexity-reducing effect and supports a structured approach.

The operational approach should further enable

- the identification of supplier potentials based on innovation indicators and characteristics,
- the structuring of the selection of innovative supplier ideas based on a clear set of criteria and
- the creation of opportunities for the introduction of innovative ideas by suppliers.

By allowing opportunities for suppliers to introduce innovations, the purchasing department is obliged to take an active managing role. Selecting and evaluating innovation ideas should be done among interdisciplinary teams so as to combine the widest possible technical and business experience. As identified in the research, the right team composition for a successful interdisciplinary cooperation plays a significant part in an onward implementation phase.

An essential component for innovation implementation is the evolution of modern purchasing management towards a value creator for the company. Among other things, one can conclude that the powers of purchasing need to be expanded in this context to encompass the following: the role of purchasing, acting as a process moderator, neutral mediator, and project supporter, equipped with social competency to cope with conflicting objectives in the interdisciplinary innovation project teams.

An important recommendation for action based on the results of the applied empirical investigation refers to the factors of a **symmetric distribution of power** and a **culture of cooperation.** In both of these aspects, the position of purchasing shows additional room for improvement. The guiding principle here appears to be to raise awareness of purchasers regarding the development of modern purchasing duties as a designer for innovation partnerships and networks. The identified requirement that innovative suppliers in joint innovations may not take advantage of their power, applies in the same sense for purchasing managers of the focal company. It is important to strengthen the awareness of creating a balance of power as well as fair-minded relationships.

ACKNOWLEDGEMENTS

The team of researchers gratefully acknowledges the contributions of the participating purchasing managers of the focal case company throughout the underlying applied research.

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BUYER-SUPPLIER INTEGRATION AND LOGISTICS PERFORMANCE IN HEALTH CARE FACILITIES IN TANZANIA: THE MODERATING EFFECT OF CENTRALIZED DECISION CONTROL

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ABSTRACT

Purpose

This research concerns logistics performance in public purchasing relationships, and explores the effect of buyer-supplier integration on supplier logistics performance. The research focuses in particular on purchasing centralization in health care facilities, and examine whether centralization of purchasing decision control exercised by the health authorities will influence the effect of buyer-supplier integration on supplier logistics performances at the firm level in health care facilities.

Design/methodology/approach

This research is based on basic organization theory, inter-organizational theory, and supply chain management literature, and examines the combined effect of purchasing centralization and supplier integration on supplier logistics performance based on survey data from 164 key informants from public health institutions in Tanzania.

Findings

The analysis reveals that stronger buyer-supplier integration improves supplier logistics performance significantly, and that stronger centralization of purchasing decision control by the health authorities reduces the effect of more extensive buyer-supplier integration on supplier logistics performance at the firm level.

Research limitations/implications

Public health institutions in Tanzania are highly regulated and controlled by public authorities, and this might limit the external validity of this study. Possible effects of opportunistic behaviour among public agents might also influence the outcome of the analyses, and further research in other empirical settings and cultural settings is desirable to test the external validity of the empirical findings.

Practical implications

The local government should focus more on supporting the individual public health facilities in developing and adapting proper governance mechanisms for their supplier integration, and be aware of the advantages associated to the alignment of independent and local supplier coordination at the institutional level.

Social implications

Strong bureaucratic decision control and possible opportunistic behaviour among public agents and employee in public medicine institutions might represent a threat against a smooth and effective organization of the medicine supplies in the public sector.

Original/value

The study provides a valuable theoretical contribution to the supply chain management research. In particular, the combination of significant contributions from basic organization theory, principal-agent theory and supply chain management literature provides a broad and interesting focus on significant antecedents to supplier logistics performance.

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Keywords: Organization theory, supplier logistics performance, purchasing centralization, supplier integration, health sector logistics.

1. INTRODUCTION

Buying firms' external integration with suppliers is a central issue of operations strategy (Koufteros *et al*., 2014, Flynn *et al*., 2010). In the literature, it has been noted that, most of the companies are more comfortable with internal than external integration (Fawcett and Magnan, 2002), and a limited progress in implementing external integration has been noted, despite various efforts to encourage external integration with suppliers and customers (Richey *et al*., 2010).

The resource based view (RBV) theory holds buyer-supplier integration as a unique dyadic resource which synchronises the core logistics competencies and capabilities of all actors to jointly achieve improved logistics performance. However it has been noted that the proposed link between buyer-supplier integration and supplier logistic performance is not straight forward. While the majority of researchers asserts that investing more in buyer-supplier integration should enhance logistic performance (Gimenez and Ventura, 2005; Stank *et al.,* 1999a), others like Das *et al*., (2006) are sceptical and suggest that this effect is rather modest. The observed inconsistencies in the literature suggest that there are other factors influencing this association, and this research examines the role of purchasing centralisation as an organizational design factor that might influence the effect of buyer-supplier integration on supplier logistics performance.

The reviewed literature on organisation theory asserts that organisation structure is an important antecedent to organizational behaviour, and this argument has been supported by evidences which demonstrate that organization's ability to integrate successfully with external actors acquires strong mobilizing of organizational resources (Teixeira *et al*., 2012), and Aiken and Hage (1971) assert that substantial centralization of decision control is negatively related to smooth organizational communication which is considered a key factor for the development of buyer-supplier integration.

Despite the importance of organization structure and supplier integration, empirical evidence is missing on how these factors are related, and little work has been done in exploring the influence of organization structure on external relationships with suppliers and customers (Koufteros *et al*., 2014). The objective of this research is to introduce a research model which relates purchasing centralization and buyer-supplier integration and examines the effects of these factors on supplier logistics performance based on the organizational design literature (Koufterous *et al.,* 2014).

This paper integrates contributions from basic organization theory and supply chain management literature, and examines the combined effects of purchasing centralization and buyer-supplier integration on supplier logistics performance in buyer-supplier exchange relationships. The supplier logistics performance model (figure 1) also controls for environmental uncertainty (UNCERT), supplier's output monitoring (SUPPLMON), geographical location (GEO), and the distance between the sites of buyers and suppliers (PROX). The research model (figure 1) depicts our research hypotheses and will be elaborated further in the next section.

2. THEORETICAL FRAMEWORK, RESEARCH MODEL AND HYPOTHESES

2.1. Theoretical Contributions

This paper employed three theoretical perspectives, (1) inter-organizational theory is used to explain the motivation for buyer-supplier integration, (2) organizational design theory is applied to shed light on how purchasing centralization influence the effects of external integration initiatives in buyer-supplier relationships, and (3) the principal-agent theory will enlighten the problems of several principals influencing the decision making in public purchasing firms.

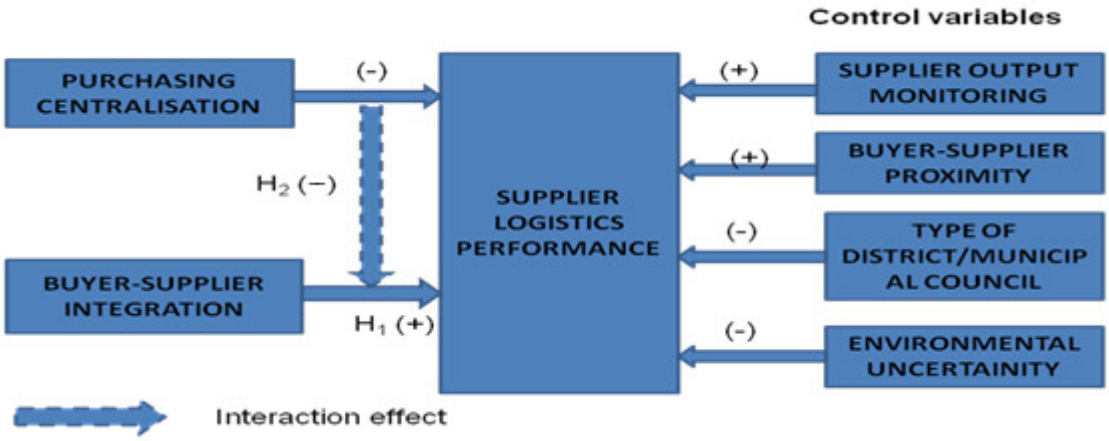

Figure 1: Research model

2.2. Centralization, Decision Control and the Problem of Several Principals in Supplier Relationships

The principal-agency theory focuses on agency problems in bureaucratic organizations, and there are in particular two key elements of the P-A theory which are relevant for public institutions, and these factors concern (1) goal conflicts and (2) information asymmetry (Waterman and Meier, 1998). In the presence of goal conflicts between multiple principals and agents, the agents tend to shirk responsibility or engage in non-sanctioned actions, while information asymmetry, on the other hand, allows agents to be less responsive to the principals and engaged in free riding behaviour.

The current study setting illustrates a situation with several principals, the buying health care facilities that put emphasis on smooth supplier integration, and the public agencies that exercise bureaucratic control over the health care institutions. Such multiple governance structures enforce the organization complexity because it is rather difficult for public bureaucracies, e.g. local government authorities (LGAs) and public health facilities to have compatible goals due to divergences in their decision focuses and responsibilities. In such a situation, the supplier becomes more uncertain about the priorities of goals and sub goals and such agency problems will also influence the

behaviour of the suppliers of health care facilities. When a supplier (agent) is caught in a web of conflicting goals exposed by bureaucracies (e.g. local government authorities) and the health facilities (the buyers), the supplier may not know the entity to respond to (Waterman and Meier, 1998), and the supplier will have an incentive to align with the principal who most closely reflects his/her basic interests.

Centralization of decision control is also associated to severe information asymmetry problems (moral hazard) because the buyer cannot closely observe the actions of the supplier. It is expected to limit the actual buyer's (principal) ability to establish close contacts with the supplier (agent) due to the presence of a central administrative block between the two actors, and hence enforce the problems associated to the implementation of effective supplier coordination and the prospects of improved supplier logistics performance (Waterman and Meier, 1998).

Based on contributions from basic organizational design theory, it is expected that centralization of buying firms' purchasing management will influence supplier logistics performance negatively. This problem concerns low collaborations between personnel (Bower, 1970) and restricted information gathering and dissemination which hinder smooth adaptability in the administration of logistics activities. It is expected that firms utilizing a centralized structure will hinder the suppliers' visibility due to the limitations of a centralized structure with respect to inter-firm interactions and smooth information flows. On the other hand, a decentralized structure has been positively associated with technical and productive efficiency due to fewer decision levels (Saltman *et al*., 2003).

Taken together, the discussion above suggest that purchasing centralization makes suppliers more unconscious of their responsibilities (Hambleton *et al.*, 1996), and reduces the suppliers' flexibility and abilities for quick responses (De varies, 2000).

2.3. Buyer-Supplier Integration and Supplier Logistics Performance

Buyer-supplier integration supports external routines and processes which collect accurate demand and supply information essential for the co-ordination of activities between buyers and suppliers (Stank *et al*., 1999a), and such coordination enables the supplier and the buyer to anticipate and coordinate inter-firm supplies more precisely (Flynn *et al*., 2010). In addition, buyer-supplier integration provides the supplier with more accurate local information about the customers for the purpose of improving the quality of the problem-solving (Flynn and Flynn, 1999).

A direct information flow between suppliers and buyers is expected to assist the suppliers in being more responsive in the performing of logistical services, such as inventory management, order processing and transportation planning. These arguments have been supported by Daugherty *et al*., (2009) who suggest that superior logistics performance can only occur when both participants work closely together, and buyer-supplier integration is the main managerial mode for value creation in a buyer-supplier relationship because it facilitates a smooth information flow by the coaching and sharing of strategic knowledge (Hammervoll, 2012).

Based on this reasoning, we propose the following refutable research hypothesis:

H1: There is a positive association between the extent of buyer-supplier integration and supplier logistics performance.

2.4. The Combined Effect of Purchasing Centralization and Buyer-Supplier Integration on Supplier Logistics Performance

The coordination of the interdependent activities and functions between buyers and suppliers requires a substantial amount of information (Galbraith, 1977). Overall, buyer-supplier integration practices facilitate co-ordination through information exchange and joint or collective actions between the buyer and the supplier. However the inherent features of purchasing centralization will reduce the effect of buyer-supplier integration on supplier logistics performance because centralization limits the quality and outcomes of inter-firm collaboration (Bower, 1970).

Furthermore, a centralized structure might reduce an open an effective information gathering and information dissemination (Jaworski and Kohli, 1993), and we will argue that purchasing centralization will limit a smooth and open interaction and collaboration between the buyer and the supplier, and will hence distort and erode the information flow.

In a public health system, the lack of decision-making authority at the health facility level will discourage proactive problem solving because the decision authority is not located and attached to the sources of local decision problems associated to local information exchange improvements or customized transportation solutions in a specific, local buyer-seller relationship.

Accordingly, we expect that some potential benefits of improved coordination and control at the micro level is likely to be suppressed or outweighed by more standardized and centralized, institutional policies (Koufteros *et al*., 2014). The current literature supports those arguments and provides some evidences showing that centralization at the micro level has negative effects on external integration (Koufteros *et al*., 2014). This study extends this reasoning, and considers centralization of decision control at the micro level to erode the potential effect of buyer-supplier integration on supplier logistics performance, and we propose the following refutable hypothesis:

H2: The association between buyer-supplier integration and supplier logistics performance decreases as the extent of the buying firm's purchasing centralization increases.

3. RESEARCH METHODOLOGY, MEASURES AND VALIDITY ASSESSMENTS

3.1. Empirical Setting and Data Collection

A survey was conducted in the public medicine supply system in Tanzania. The target population was all categories of public health facilities (hospitals, health centers and dispensaries). A stratified random sampling technique was used to select 215 public health facilities. The unit of analysis was the dyadic exchange relationship between a public health facility and its focal supplier (Medical Supplies Department, MSD).

A questionnaire was developed and used to collected data, and all measures were adapted from previous studies in inter-organizational research. The construct items were measured by a seven point Likert scale.

The original questionnaire was written in English, translated into Kiswahili, and then retranslated into English to ensure data quality.
A pilot study was then carried out in 35 public health facilities, and the obtained feedback was used to modify and develop the questionnaire wordings further.
Data was collected by using key informants from the purchasing departments of the sampled health facilities in Tanzania.
The average work experience of the key informants was 6 years, and indicates that they had sufficient experience with respect to the purchasing practices and supplier evaluations. A total of 164 questionnaires were completed and provide a response rate of 77%.

3.2. Measure Development

In the following section, we describe the basic contents of the constructs appearing in our research model. Table 1 below provides a detailed overview of the items composing our scales. All measures were adapted from previous similar studies in inter-organizational research.

Table 1: Scales and Reliability Measures

Scales:	Sample of items. *Response format*: 7-point Likert-type scale with end points inaccurate description and accurate description.
SUPPLPERF Supplier Logistic Performance 6 items α=0.90	SUPPLPERF1:We regularly experience on timely delivery of essential drugs from the MSD SUPPLPERF2:We always experience consistency on the MSD order fill capacity SUPPLPERF3:We regularly experience satisfactory lead time from the MSD SUPPLPERF4:We always experience satisfactory lead time on the back order delivery SUPPLPERF5:We always experience high accuracy on order delivery from the MSD SUPPLPERF6:We always experience complete order delivery from the MSD
SUPPLINT Buyer-supplier integration 6 items α= 0.84	SUPPLINT1: Our purchasing unit and the MSD always work together as a team to solve essential drug supply-related problems. SUPPLINT2: Our purchasing unit and the MSD always work together in following up of our essential drug orders sent SUPPLINT3: Our purchasing unit always collaborates closely with the MSD on quality control of delivered essential drugs SUPPLINT4: Our purchasing unit always collaborates closely with the MSD on quality control of delivered essential drugs SUPPLINT5: Our purchasing unit and the MSD have closely integrated the supply of essential drugs and other drugs in vertical programs SUPPLINT6: Our purchasing unit and the MSD always hold periodic meetings to plan for our drug supply.
CENTRAL Purchasing centralisation 4 items α= 0.79	CENTRAL 1: All decisions on supplementary funding for drug purchasing have to be made by the regional or district government authority (DMO/ RMO). CENTRAL 2: All decisions on purchasing from other suppliers have to be made by the regional or district government authority (DMO/ RMO) CENTRAL 3: All decisions we make on ordering must be approved by the regional or district government authority (DMO/ RMO) CENTRAL 4: All decisions on financial matters to support drug purchase must have an approval from the regional or district government authority (DMO/ RMO)
SUPPLMON Supplier's output monitoring 5 items α=0.86	SUPPLMON 1: We frequently monitor the MSD delivery timeliness SUPPLMON 2: We always monitor the MSD delivery accuracy (conformity to order) SUPPLMON 3: We frequently monitor the MSD's lead time (time between ordering and delivery) SUPPLMON 4: We always monitor the MSD's time on backorder delivery. SUPPLMON 5: We regularly monitor the MSD's stock out rate.
UNCERT Environmental uncertainity 4 items α= 0.76	UNCER1: Our essential drug demand fluctuates regularly from time to time UNCER2: Our essential drug supply fluctuates regularly from time to time UNCER3: Our essential drug prices fluctuate regularly from time to time UNCER4: Our health facility always has high variation in patients mix for a particular essential drug

Supplier Logistics Performance (SUPPLPERF). Six items compose this scale. The construct captures how well the buying firm perceives the performance of their zonal medical supplier with respect to on time delivery; order filling capacity, lead time and accuracy in order delivery.
*Purchasing Centralization (CENTRAL).*This measure describes the extent of autonomy in purchasing decision making residing with the purchasing managers and is composed by four items.
*Buyer-supplier Integration (SUPPLINT).*This construct measures the extent of inter-firm coordination and collaboration between a public health facility and its focal supplier of essential medicines, and is measured by 6 items.
Supplier's Output Monitoring (SUPPLMON). This construct describes the verification of the delivery based on product quality, delivery timelines, and order accuracy and is composed by 5 items.
Environmental Uncertainty (UNCERT). These items measure the level of unpredictability in the exchange environment of the health facility, and the scale is composed by four items.
Geographical Location (GEO). This is a dummy variable that indicates the location of the public health facility in a rural (value1.00) or urban (0) council.
*Buyer-supplier Proximity (PROX).*This is a ratio scaled variable measuring the geographical distance, assessed by the number of days spent on transportation between the public health facility and its zonal medical supplier.

3.3. Validity Assessments and Descriptive Statistics

First, an exploratory factor analysis was carried out based on Eigen values, and the analysis assigned all the items of the five constructs into five factors explaining a total of 63% of the total variance.

Table 2: Correlation Matrix, average variance extracted (AVE) and Descriptive Statistics

Contracts	1	2	3	4	5	6	7
1.CENTRAL[a]	1.00	0.02	0.03	0.001	0.02	0.01	0.001
2.SUPPLINT[a]	-0.15	1.00	0.26	0.001	0.27	0.02	0.01
3.SUPPLPERF	-0.17*	0.51*	1.00	0.002	0.25	0.04	0.001
4.UNCERT	0.03	0.03	-0.04	1.00	0.001	0.001	0.01
5.SUPPLMON	-0.13	0.52*	0.50*	0.01	1.00	0.03	0.01
6.GEO	0.11	-0.13	-0.20*	0.01	-0.16*	1.00	0.06
7.PROX	-0.03	-0.08	0.01	0.09	-0.10	0.24*	1.00
Mean	0.00	0.00	3.14	4.69	3.99	0.64	1.55
S.d	1.44	1.49	1.54	1.34	1.59	0.48	0.67
AVE	**0.50**	**0.46**	**0.59**	**0.44**	**0.56**		

Note: Values above the diagonal are the shared variances between constructs, while those below the diagonal are the inter-construct correlation estimates.
* Correlation is significant at the 0.05 level (2-tailed).
[a] mean centered variables

All factor-items loadings were above 0.4 for each of the constructs, and indicate satisfactory internal consistency (Hair *et al.*, 2006), and all constructs had Cronbach alpha values above 0.7 (confer Table 1) and provide further support for satisfactory data reliability (Nunnally, 1981; Pallant, 2010).
A confirmatory factor analysis (CFA) was carried out by Amos and resulted into a satisfactory model fit indices were; χ^2 =352.2 df 262, p<0.01, IFI =0.951; TLI =0.95; CFI =0.95. All indices fell within the cutoff point of 0.9 (Byrne, 2010), and the RMSEA value (0.046) was within the 0.05-limit as proposed by Byrne (2010). All factor loadings were significant and greater than 0.5 with t-values > 2.00, and demonstrate satisfactory convergent validity for the model (Droge *et al.*, 2004).
Discriminant validity was assessed by using the procedures of Fornel and Larcker (1981). The estimated average variance extracted (AVE) was greater than the percentage of variance shared by each construct (confer Table 2) except for buyer-supplier integration (SUPPLINT) and environmental uncertainty (UNCERT) which had AVE-scores below 0.5, 0.46 and 0.44 respectively. However, the discriminant validity assessments revealed that SUPPLINT and UNCERT satisfied the other criteria above and support satisfactory discriminant for the research model. The moderate AVE-values may be explained by the fact that this is the first time the variables are tested in a health care setting.

4. DATA ANALYSIS AND EMPIRICAL FINDINGS

4.1. Regression Analysis and Model Fit

In this paper a moderated multiple regression(MMR) analysis was used to estimate the model because it is superior to Structural equation modelling (SEM) when measures' reliabilities are high and the sample size is small (Jaccard and Wan, 1996). In addition, this paper used continuous variables, and hence MMR explains more variance than a sub-group analysis in SEM (Aiken and West, 1991; Cohen and Cohen, 1983; Jaccard *et al.*, 1990).

In order to test our research hypotheses, the following OLS-regression model was estimated:

$$\text{SUPPLPERF}=b_0 + b_1\text{CENTRAL} + b_2\text{SUPPLINT} + b_3\text{SUPPLMON} + b_4\,\text{UNCERT} + b_5\text{GEO} + b_6\,\text{PROX} + b_7\text{SUPPLINT x CENTRALxSUPPLINT} + e$$

The model (confer Table 3) demonstrates satisfactory goodness of fit with F (7,156) = 13.56, p<0.01), R^2_{Adj} = 0.35, and shows that the model provides an adequate description of our data. All constructs (SUPPLINT and CENTRAL) entering the interaction term were mean-centered in order to handle possible collinearity problems (Jaccard and Turrisi, 2003), and the moderate VIF-measures in Table 3 show no signs of critical multi-collinearity problems for any constructs.
By using the approach suggested by Jaccard and Turrisi (2003), a test of the significance of the two-way interaction effect (CENTRAL x SUPPLINT) was carried out. This test assesses the significance of an interaction effect by measuring the change in R^2 when the interaction term is added to the regression model. The results demonstrated that when the interaction term (CENTRALxSUPPLINT) was introduced into the regression model, the model's explanatory power increased by 0.02 (2%). This

corresponds to an F-value of 4.55 and exceeds the critical F-value of 3.84 for F (1,156) at a significance level of $p<0.05$, and demonstrates that the interaction term contributes significantly to the explanatory power of our model.

Table 3: Regression Analysis: Dependent Variable: Supplier Logistics Performance

	Unstandardized Coefficients (b)	t values	Collinearity Statistics	
			Tolerance	VIF
(Constant)	b_0 =2.238	4.301***		
CENTRAL[a]	b_1 =-0.03	-.46	.911	1.098
SUPPLINT[a]	b_2 =0.33	4.28***	.715	1.399
SUPPLMON	b_3 =0.30	4.18***	.714	1.401
UNCERT	b_4 =-0.10	-1.39*	.945	1.058
GEO	b_5 =-0.42	-1.99**	.913	1.095
PROX	b_6 =0.27	1.79*	.920	1.087
CENTRALxSUPPLINT	b_7 =-0.10	-2.13**	.901	1.109
Model fit: F(7, 156) =13.566 ($p<0.01$); R^2= 0.38, R^2_{Adj} = 0.35				

*p<0.10, **p<0.05 and p***<0.01 a = mean centered variables

4.2. Empirical Findings

According to Jaccard and Turissi, (2003), the main effects of each of the variables entering interaction terms express their effect on the dependent variable when the value of the variable with which they interact is zero. H1 corresponds to the main effect of buyer-supplier integration on supplier logistic performance when the level of centralization (CENTRAL) is zero. This corresponds to the mean level of centralization as the variables entering the interaction term were mean-centered. The regression output supports H1 (b_2 = 0.33; t = 4.28, $p<0.01$), and the findings demonstrate that supplier-buyer integration on its own has a direct influence on supplier logistics performance.

H_2 expresses the combined effect of centralization of purchasing decision control in buying firms (CENTRAL) and buyer-supplier integration (SUPPLINT) on supplier logistic performance (SUPPLPERF). The regression results support H_2 in the sense that the interaction effect (CENTRAL x SUPPLINT) is negative and significant (b_7 = -0.10, t =-2.132, $p<0.05$).

An elaboration of this interaction effect was carried out by estimating the effects of buyer-supplier integration on supplier logistic performance at different levels of purchasing centralization as recommended by Aiken and West (1991) and Schoonhoven (1981)[1].

(1) $\delta SUPPLPERF/\delta SUPPLINT = b_2 + b_7 CENTRAL$

[1] Estimated effects of buyer-supplier integration on supplier logistics performance at different levels of purchasing centralization (+/-2 scale units, s.u). Recall that CENTRAL and SUPPLINT are mean-centered.

By inserting the data from the regression outputs, we get:

(2)δSUPPLPERF/δSUPPLINT = 0.33 -0.10*CENTRAL

The analysis below demonstrates that the effect of buyer-supplier integration on supplier logistics performance was significantly weakened as the extent of centralization of the decision control in the buying firm increased:

Value of centralization (CENTRAL):	Low (-2 s.u)	Mean	High (+2 s.u)
δ SUPLPERF/ δSUPPLINT:	0.53	0.33	0.13
Significance: t-values	4.31	4.30	1.06

The figures in the table above demonstrate that at low and medium levels of centralization (CENTRAL), the effect of supplier integration (SUPPLINT) on supplier logistics performance (SUPPLPERF) is significant and high (the slope is 0.53, $p<0.01$ and 0.33, $p<0.01$ for these levels). This effect vanishes when centralization increases to a "high" level where the slope is 0.13 ($p>0.10$), and demonstrates how substantial centralization of decision control erodes the effect of supplier integration on supplier logistics performance.

4.3. The Effects of Control Variables

The geographical location of the health facility (GEO) has a significant and negative effect on supplier logistics performance (b_5 = -0.42, t =-1.99, $p<0.05$), and this implies that public health facilities in rural district councils experience lower supplier logistics performance than those in urban councils.
Supplier output monitoring (SUPPLMON) has a strong positive effect on supplier logistics performance (b_3 = 0.30, t =4.18, $p<0.01$). This finding is in line with basic principal-agent reasoning, and demonstrates that the more the health facilities enforce their monitoring verification of their suppliers, the higher is the supplier logistics performance.
Environmental uncertainty (UNCERT) is negatively associated to logistics performance (b_4 =-0.10, t=-1.39, $p>0.10$), but the association is not significant. Finally, the empirical findings also demonstrate that the distance between the public health facilities and their zonal supplier (PROX) has a slight negative effect on supplier logistics performance (b_6 = -0.27, t =-1.79, $p<0.10$). This finding indicates that those health facilities residing far away from their focal supplier experience lower supplier logistics performance than closer ones. This might concern practical problems associated to the implementation of activities aiming at improving logistics activities when the geographical distance between buyers and suppliers becomes large.

5. DISCUSION, IMPLICATIONS AND FUTURE RESEARCH

The main objective of this paper was to examine the combined effect of purchasing centralization and buyer-supplier integration on supplier logistics performance. The empirical findings show that substantial centralization of purchasing decisions in public

institutions weakens the effects of buyer-supplier integration on supplier logistics performance. This supports previous scholars (Koufterous *et al*., 2014) who assert that there is a negative association between purchasing centralization and customer integration, indicating that extensive supplier integration should not be paired with substantial centralization of buying firms' decision control. Similarly, others scholars like Aiken and Hage (1971) and Galbraith (1974) argue that substantial centralization of decision control erodes organization communications and information flows and the buying firms' abilities to implement smooth and effective supplier integration.

These arguments are strongly relevant in studies of buyer-supplier relationships because substantial centralization of decision control at the firm level seems to impair buyer-supplier interactions and collaborations which are key factors in improving the logistical operations at the supplier side.

Most of the daily inter-organizational contact points in business operations reside at lower organizational levels and line managers who are local experts on purchasing requirements, and hence they are in a better position to mediate relevant information and demands to suppliers in order to improve logistics activities. If they are denied such an autonomy option, the information gaps between the two actors will be enforced with successive reduction of the potentials for improved supplier's performance.

The findings of this study provide some evidence for a strong and positive effect of buyer supplier integration on supplier logistics performance and support previous research contributions by Devaraj *et al*., (2007) who examined the effect of supplier integration on operational performance, and demonstrated that supplier integration is a key factor for improving supplier logistics performance. However, our study also contradicts with other scholars like Swink *et al*., (2007) in the sense that our study did not observe any main effect of purchasing centralization on supplier logistics performance.

Theoretically, this research provides important knowledge to the administration elements of the supply chain management literature, and extends Vora's (1992) arguments concerning the fruitfulness of integrating constructs and reasoning from basic organizational theory and other fields of inter-organizational theory into supply chain management research. The organization design theory has a relatively long and strong tenure in management research even if its research applications in recent years has somewhat waned (Koufterous *et al.,* 2014). This paper supports (Koufterous *et al.,* (2014) who claims that there is still substantial values and perspectives in organizational design theory that contribute to the existing debate on the effects of supply chain integration on logistics performance (Fabbes-Costes and Jahre, 2008),

For managers and policy makers, our findings demonstrate the importance of looking into the interplay of several organizational factors based on an organizational design approach in the search for improved logistics performance in supplier relationships. The reason for this is that the marginal effects of logistics decisions and activities might be contingent on both intra-firm organizational capacities and motivation, this article has advocated the need to decentralize tactical and operational decision making to operations managers at the firm level in order to improve supplier logistics operations and logistics performance.

This study is based on a cross-sectional survey design with data collected only from the buyer's side. However, relational variables such as buyer-supplier integration may require time to realize their potential effects, and therefore future studies should consider a longitudinal approach based on data from both sides of business relationships in order to explore this further.

Furthermore, public health institutions in Tanzania are highly regulated and controlled by public authorities, and this might limit the external validity of this study. Possible effects of opportunistic behaviour among public agents might also influence the outcome of the analysis, and further research in other organizational settings and cultural settings is desirable to test the validity of the empirical findings further.
This study used only one dimension of organisation structure "centralisation", and it is desirable in future research to incorporate other organizational dimensions like formalisation and standardisation when exploring antecedents to supplier logistics performance.

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DYNAMIC ROUTING IN REVERSE LOGISTICS:
The effect of sensors in waste containers on uncertainty

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ABSTRACT

Purpose
Reverse logistics systems are characterized with inherent uncertainties from supply and demand. Therefore, tools and planning methods must be developed to cope with these uncertainties and at the same time reduce cost and increase service and predictability. This paper develop a dynamic method for vehicle routing in waste collection. In particular, we evaluate the effect of availability of fill-rate data provided by sensors in waste containers.

Design/methodology/approach
Through a computer simulation, the paper compares the total haulage distance, service level and capacity utilization of a waste collection system in two cases: (1) When there is no sensor installed in containers and vehicles follow fixed routes and fixed schedules to collect waste throughout the year. (2) When there are sensors installed and a dynamic routing algorithm determine which containers and in what order to be emptied each day. The needed data is taken from the existing system in the municipality of Oslo. The dynamic routing algorithm is developed based on a static algorithm, Clarke-Wright, but redesigned for the in-hand case.

Findings
The results show significant improvements in all of the compared metrics. Following these improvements we argue that this dynamic way of working with collection reduce the uncertainty level of reverse logistics system.

Practical implications
Information collected from sensors together with a dynamic method, is used to determine the containers to be emptied each day and the corresponding routes. The consequence is that the reverse logistics system is more adapted to the consumers' return behavior, and uncertainty of the system is reduced.

Original/value
The paper demonstrates how development of a dynamic routing algorithm contributes to increase efficiency in reverse logistics systems.

Keywords: Reverse logistics, Uncertainty, Vehicle Routing, Dynamic routing, Waste containers

1. INTRODUCTION

The motivation for this research comes from the fact that reverse logistics is a business that is increasing in scope and scale Increasingly, more sorting of waste is implemented at the source. This has logistics implications, as more sorting needs more adapted logistics to different reverse flows. Following such a development, it is important to secure reverse logistics systems that is cost efficient, provide high service levels and safeguard positive environmental effects.

Reverse logistics may be defined as "*The process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturer, in distribution or use point, to a point of recovery or point of proper disposal*" (de Brito and Dekker (2004:5). Rubio *et al.* (2008) identify that this definition is the most complete in current research. A challenge with reverse logistics is that the starting point have the characteristic of being unpredictable. Waste is the raw material of the system, and it is uncertain when products are defined at end-of-life. This characteristic may be viewed as one of the more central to the system, because if the system does not start of properly, the whole system might be inefficient. Therefore, the initiation phase is one of the more important functions to understand in reverse logistics systems.

In this paper we want to investigate a method that makes it possible to have better adaptation to these uncertainties. In particular we explore the adaptation of transport capacity for collection. We look into a service with fixed routes, where transport is sent to attend to a number of collection routes, and it is based on an average expectation that the collection containers are filled. The reality is then that some are and some are not. By using sensors it is possible for the transport service to be planned dynamically. That is, to plan new routes for every collection based on the fill-rate of the containers. This would increase the performance of the system, by saving cost, increasing service and reducing the environmental impact.

The paper is structured as follows. We continue with the literature review, and then we present the research design, before we introduce the algorithm and the simulation model. Following these methodological parts of the paper, we present the result of the analysis before we summarize conclusions.

2. LITTERATURE REVIEW

The literature demonstrate great many reverse logistics systems (Rubio *et al.*, 2008). However, one characteristic cut across many of these systems, and that is the inherent uncertainty that the systems face. Guide *et al.*, (2000) discuss characteristics that increase uncertainty, and argue that managers must take action to reduce these uncertainties. The factors are developed based on a recoverable manufacturing environment, and include (1) the uncertainty of timing and quantity of returns, (2) the need to balance demands with returns, (3) the need to disassemble the returned products, (4) the uncertainty in material recovered from returned items, (5) the requirement for a reverse logistics network, (6) the complication of material matching restrictions and the (7) problems of stochastic routings for materials for repair and remanufacturing operations and highly variable processing times.

Recycling is a more simplified reverse logistics system than refurbishing and remanufacturing recovery (Thierry *et al.*, 1995), as it passes through fewer steps and functions in the process.

Complicated products like vehicles, consumer electronics and general electric products, need a sophisticated reverse operation in order to be available for a secondary market. Simpler products like packaging need not the same level of treatment (Kroon and Vrijens, 1995). However, some of the uncertainties remain. We argue that the uncertainty of timing and quantity of return constitute a common uncertainty in all types of reverse logistics systems. Basically, we could say that if the reverse systems does not get this right, the subsequent steps will have a reduced success level per se. Reverse uncertainties have been investigated for closed loop supply chains (Inderfurth, 2005), and demonstrates that it is difficult to get a hold of sufficient volumes of return (Biehl *et al.*, 2007). However, the potential is high as consumers actually hold recycling in higher regard than other product recovery options (Hazen *et al.*, 2011).

The reverse logistics process starts with the consumer of products (Anderson and Brodin, 2005). In fact, the consumer becomes the supplier in reverse logistics systems (Goggin *et al.*, 2000). It follows from the nature of consumption that each consumer have individually behavioral patterns. These patterns are reflected in returns, and is referred to under the label of uncertainty in timing and quantity (Guide *et al.*, 2000). It is not for sure when a consumer have completed the consumption and is ready to return the product (timing). Further, it is not for sure if the consumer will choose the preferred return option for the product either, leaving the receiver uncertain of which level of volume to plan for (quantity). In addition, the consumer is a passive supplier of products (Pohlen and Farris, 1992). Consumers are in other words, unpredictable in delivery of their products to the reverse logistics system. This lack of compliance can have great financial losses (Breen, 2006).

Reverse logistics is growing in scope and scale, when increasing number of waste types are subject to sorting and recovery operations. It is traditionally an area without too high earnings, but still a high co_changesst level (e.g. Johnson, 1998). It is an area where it is vital to keep the cost under control, as waste itself is not a valuable product per se. However, it might be earnings to gain if products are delivered with high quality at the end of the pipeline to secondary markets (Fleishmann *et al.*, 1997). Thus, the quality of the process itself is important. In fact, investments in reverse logistics capabilities are demonstrated to contribute to cost savings (Jack *et al.*, 2010).

The challenge of uncertain supplies to a reverse logistics system is that the subsequent logistics system will also incur greater uncertainties and inevitably higher costs. The capacity planning in a logistics system is an important cost driver, and when this is unpredictable, it is difficult to control cost. In addition it is also difficult to provide a well adapted service level, when it is unknown what the demand is. Finally, this takes us back to the goal of reverse logistics itself, that it is itself a measure to cope with environmental challenges. It is therefore a paradox that the logistics system process have wasteful operations, if these uncertainties are not countered. The effect is strengthened in the recycling recovery option, where it is found that cost control is the primary objective (Gobbi, 2011).

We argue that the interface between the uncertain supplier and the reverse logistics network is important in order to secure a cost effective reverse logistics system, but also provide necessary service to the consumer as the supplier of the system. Fleishmann *et al.* (1997) state in this early study that for distribution planning, uncertainty have implications for the network structure, and explicitly they mention how the transportation function are influenced by high or low quality products. High quality products justify higher transportation costs, whereas low quality products, logically, have to economize on transportation. Bautista and Pereira (2006) discuss

the function of locating collection areas. They find that a well adapted placement of collection areas can increase the level of recyclable products and the perceived quality of service. In fact, the ability to design the collection function properly may actually induce the consumers to increase their returns, and in this manner reduce uncertainty levels of reverse logistics systems.

3. RESEARCH DESIGN

The case we have chosen in order to evaluate the interface between the customer and the reverse logistics system, and how uncertainty may be countered, is the transport service towards the collection point for glass and metal recycling in Oslo (Cammermeyer and Lunde 2014). The Agency for Waste Management in Oslo have designed a bring (Jahre 1995) type reverse logistics system for glass and metal waste. It starts with a container that is located in a brief range from the household, and consumers have to bring their waste to this point. Then, a transport service provider run a collection service towards these collection points. The uncertainty is manifested in terms of the unpredictability in the fill-rate of the containers. The transport service provider run a static routing scheme to empty the containers, and the containers are attended to even if they are not filled or filled. Thus, it is an imprecise capacity utilization of the transport service, because the waste volumes are uncertain. To cope with this challenge, the AWM have decided to invest in sensors that will measure fill-rate, and this measurement will give the transport service provider the possibility to attend to full containers only. This change is a way to mitigate uncertainty, and we will in this paper investigate the effect of the sensors on service and cost.

3.1. Case description

There are 1003 glass and metal waste containers around the municipality of Oslo including 545 4000-litre, 22 2500-litre, 177 1100-litre, 188 private and 71 800-litre containers. These containers have 851 locations. Currently two trucks are in charge of evacuating the containers. Each container is always emptied by a fixed truck. Based on how fast the containers are filled (estimated fill-rate), they are divided into 3 groups: (1) those that are emptied every week, (2) those that are emptied every other week and (3) those that are emptied every 4 weeks. Therefore, each year, only by knowing the first week when a container is emptied, all other evacuation weeks of that container will also be known. In addition, every four weeks the same containers will be emptied. That is, for example, the containers which are emptied in week 3, are exactly the same as those which are emptied in weeks 7, 11, 15, etc., no matter how frequently they must be emptied.

If a container is not emptied before it becomes completely full, waste will be placed by the side of the container. This bears many problems including customer dissatisfaction. In such cases customers can ask AWM to empty the container immediately. In this paper, to estimate the cost of containers being overloaded, we have assumed that in such cases, a dedicated vehicle will be sent to that container from the depot.

Currently, a sorted list of containers to be emptied is given to each truck at the beginning of each week. The trucks visit the containers accordingly and empty them if they are more than 5% full. However, in case there is less capacity left in a truck than the total capacity of the next container, the truck will get back to the central depot of AWM, empty the waste and drive to the next container in the list. Also, if a container is so overloaded that cannot be emptied by the truck (there is less capacity left in the truck than the amount of waste in the container), the

vehicle will take as much waste as possible, drive back to the depot, become evacuated and go back to the same container. After emptying each container, if there is not enough time left to the end of working hours to drive to the next container and empty it, the driver will drive back to the depot. Next day, they will start from the next container in the list. Drivers normally work Monday to Friday. However, in case there are containers in the list that are not emptied yet at the end of the working hours on Friday, they have to empty them on Saturday.

3.2. Methodology

We investigate this challenge by comparing the current method of routing of the trucks with a new method based on the sensors. The existing method or in other words, the as-is situation, is referred to as the *Static* routing, where the visiting order of the containers is determined by the so-called *Nearest Neighbor* algorithm. The new method will be referred to as the *Dynamic* method. The methods are based on vehicle routing problems (VRP) (Toth and Vigo, 2001). We develop a dynamic algorithm based on the Clarke-Wright algorithm (Clarke and Wright, 1964). Finally, we do a simulation were we compare the static and the dynamic methods. We close the study with a sensitivity analysis of the results on the different values of dynamic evacuation proportions. The sensitivity analysis makes it possible to trade off between capacity utilization and haulage distance on one hand and service level on the other.

3.2.1. The rationale for the static and dynamic method

The Static routing by the Nearest Neighbor algorithm represents how the system is being operated per today. As described before, based on the method to make the weekly list of the containers to be emptied, there are 4 such weekly lists for each truck. The list which is used for week 1 is the same as the list being used for weeks 5, 9, 13, 17, etc. Similarly, the weekly list of week t is the same as the weekly list of weeks $t + 4k$ for $= 1, 2, 3, \ldots$. The order of the containers in each weekly list is always fixed. Therefore, since neither the weekly lists nor the order of the containers depend on how full the containers are, the current method of routing of the trucks is static routing. The visiting order of the containers is determined by the Nearest Neighbor algorithm, where the first container in the weekly list to be visited is the container that is the closest to the depot. The second one is the closest unvisited container to the first one. The third one is the closest unvisited container to the second one and so on.

As a result, by the current static method, the containers might be emptied too soon (i.e. when they are too empty) or too late (i.e. when they are full and waste is left outside the container). Furthermore, the nearest neighbor method of routing the vehicles, although very fast and easy to apply, is outperformed by other more complicated routing algorithms when it comes to producing shorter routes (Toth and Vigo, 2001). Therefore, the current static method can lead to extra haulage cost either because of unnecessary visit of the containers or using an ineffective routing method. And, the current situation might lead to customer dissatisfaction because of not emptying containers when needed.

By contrast, in the presence of the sensors, a new alternative method is referred to as the *Dynamic* method. This is because both the chosen containers and the vehicle routes depend on the utilized capacity of containers and can change every time. Daily lists can be created where the containers are selected according to how full they are at the moment. Therefore, there will be both fewer dissatisfied customers and fewer unnecessarily visited containers. In addition, a more effective routing method can be employed to reduce the haulage distance and hence the haulage cost.

3.3. Problem summary

All in all, to see whether the cost of sensors pay off or not, two main research questions can be formulated as follows:

(1) How and to what degree can the dynamic method contribute to improvement of customer service level?
(2) How and to what degree can the dynamic method reduce the total haulage distance?

Subsequently, other more detailed questions arise such as "How full should a container be to be put in a daily evacuation list?" or "How should the vehicles be routed to visit the containers in daily evacuation lists?"

In order to answer the research questions, in the next section, the dynamic method will be explained in more detail. Afterwards, through a computer simulation, the dynamic and the static methods will be compared with respect to both haulage distance and customer service level. Finally, by sensitivity analysis on the minimum level of utilized capacity in a container to be emptied, we find a proper level by trading off between customer service level and haulage distance.

4. THE DYNAMIC VEHICLE ROUTING ALGORITHM AND SIMULATION

In this chapter, we study how to solve the dynamic vehicle routing problem effectively and efficiently. Furthermore, by developing a computer simulation, the performance of the current static system is compared to the dynamic system using sensors.

4.1. Developing the dynamic routing method

In order to route the vehicles dynamically at the beginning of each working day, the list of containers to be emptied by each vehicle must be generated first. These lists are created according to the data collected from the sensors. A sensor shows the real-time utilized capacity of a container in liters, and is referred to as the *level* of the container hereafter. All of the containers whose level is at least 80% of their capacity are put into the daily list.

Now, the routing problem is, "given a list of containers, their levels, distances between the containers, capacity of the vehicles and the working hours, which containers should be assigned to each vehicle and in which order shall the vehicles visit the containers to have the shortest haulage distance?"

4.1.1. Vehicle routing optimization

This problem belongs to a family of optimization problems namely Vehicle Routing Problems or VRPs (Toth and Vigo, 2001). In a VRP there are a number of customers (in this case, containers) each of which has a known demand (in this case, level of waste). There are also vehicles that must serve the customers. The vehicles start their *tours* from a central *depot*, visit a number of customers to serve them and get back to the depot. In most of the cases, the capacity of the vehicles is assumed to be limited. Then the VRP is called *Capacitated Vehicle Routing Problem* or CVRP (Laporte *et al.*, 1985). The aim is to determine the tours such that the total mileage (haulage distance) of the vehicles is minimized while the demand of all of the customers is satisfied and the capacity constraint of the vehicles is not violated. When each

customer has a certain time window, it can only be served within which, the problem is called VRPTW (Lenstra *et al.*, 1988) or Vehicle Routing Problem with Time Windows. When both capacity limitations and time windows exist at the same time, the VRP is denoted by CVRPTW.

Here, we have a specific version of CVRPTW where the vehicles have also limited operation time. Solomon (1987) have formulated this problem in the form of a mathematical optimization problem. In this formulation, the level of each container cannot exceed the capacity of the vehicle. Moreover, the duration of daily working time is not included in the model.

However, that is not a problem since the original formulation of VRP can be easily adjusted to take into account such case-specific features. In addition, as we will see in section 4.1.2, the main issue in practice is also to find an efficient solution algorithm for the problem. Nonetheless, we have designed the solution algorithm in the next section such that both of the mentioned issues are taken care of.

There are many research works that have specifically studied vehicle routing optimization in the context of waste management. However, they are mostly focused on static routing, i.e. no real-time data on level of waste in containers is available. They normally tackle the problem by setting fixed evacuation frequencies for the containers based on their average fill rate. In addition, the objective is normally minimization of haulage distance or number of vehicles, while in our paper, in addition to these, we try to increase service level and capacity utilization. Hemmelmayr et al. (2013) have reviewed a number of such studies. They have also developed a method for allocation of bins to collection locations and routing at the same time. Buhrkal et. al. (2012) have proposed an Adaptive Large Neighbourhood Search algorithm for the capacitated vehicle routing with time windows for waste collection. They show that this method can significantly decrease haulage distance, but they did not study other performance metrics such as capacity utilization. Huang and Lin (2015) have developed a bi-level optimization model to find the collection points (location of the containers) as well as to find the split-delivery waste collection routes. They try to minimize the distance travelled and the number of vehicles but not to maximize the capacity utilization of the containers. Although their method leads to better service level for the customers, they have not studied service level in a stochastic environment. Bing et al. (2014) studied the effect of routing optimization on the sustainability (travel distance reduction) of plastic waste collection in Netherland under different scenarios.

Among the literature that has studied dynamic routing in waste collection, two must be noted. Johansson (2006) has shown that dynamic routing of the waste collection vehicles based on real-time data received from wireless sensors in Malmo contributes to “lower operating costs, shorter collection and hauling distances, and reduced labour hours” in comparison with static routing. Although he has not addressed capacity utilization of the containers, he showed that using real-time data for dynamic routing can lead to fewer number of containers. Rovetta et al. (2009) have also developed a system for dynamic routing and scheduling of waste collection system in Pudong, Shanghai. However, they have also mainly focused on minimization of haulage distance.

4.1.2. Dynamic routing algorithm

There are a number of exact (global optimization) algorithms for the VRP (Cordeau *et al.*, 2006) that theoretically can find the mathematically optimal solution of VRP. However, since the VRP is an NP-Hard problem (Lenstra and Kan, 1981), complexity is a big issue. That is, for very large cases of VRP with many nodes (containers) exact algorithms cannot necessarily be used since the optimal solution cannot be found in reasonable time. Therefore, many heuristic

algorithms including construction heuristics, improvement heuristics and meta-heuristic algorithms (Cordeau *et al.*, 2006) are developed that can return good solutions for large samples of the VRP in reasonable time.

Clarke-Wright algorithm (Clarke and Wright, 1964) is one of these heuristics that has been applied successfully to many real-world cases of the VRP. This algorithm works as follows:

1. If 0 denotes the depot, for each container i make a separate tour as $0 \rightarrow i \rightarrow 0$.
2. Calculate *savings* for each two containers. The saving for containers i and j means the saving in haulage distance when the corresponding tours of i and j are merged. In other words, instead of the two separate tours $0 \rightarrow i \rightarrow 0$ and $0 \rightarrow j \rightarrow 0$, a single vehicle serves both i and j in one tour as $0 \rightarrow i \rightarrow j \rightarrow 0$. If s_{ij} denotes the saving when the corresponding tours of i and j are merged and d_{ij} denotes the distance between i and j, then:

$$s_{ij} = d_{0i} + d_{j0} - d_{ij} \qquad (1)$$

3. If the list of savings is not empty yet, find the pair of i and j that gives the highest s_{ij}. Otherwise, terminate.
4. If the following conditions are satisfied, then make a new tour by removing $0 \rightarrow i$ and $j \rightarrow 0$ and joining $i \rightarrow j$. Otherwise, delete s_{ij} from the list and get back to step 3.
    a. $s_{ij} \geq 0$
    b. Both i and j are directly accessible from 0
    c. i and j are not already in the same tour
    d. Making the new tour will not violate the capacity or time constraint of the vehicle

The above algorithm can be revised easily such that each vehicle can have multiple tours within working hours. Only in the 4th step we must additionally check that the total duration of the tours of a vehicle (including both haulage times and emptying times) does not exceed daily working hours.

However, this algorithm still does not totally fit the problem in hand. The reason is, theoretically, the level of an overloaded container can exceed the capacity of a vehicle. Furthermore, there might be too many containers in daily evacuation list that it is impossible to empty them in one day. However, we have modified the algorithm as follows to customize it for this case.

1. If there is a container whose level is higher than the capacity of the vehicle, then it will be temporarily turned into more than one container at the same location, such that sum of their levels is the level of the aforementioned container. Moreover, the levels of all but one of the new containers must be the same as the vehicle's capacity. Each of the new containers with the level as high as the capacity of the vehicle will have a dedicated tour from/to the depot.
2. After the completion of Clarke-Wright algorithm, if sum of the haulage times and evacuation times is greater than the working hours per day
    a. The tours are sorted in descending order with respect to the utilized capacity of the vehicle.
    b. Then, we begin from the top of the sorted list of the tours. Considering the haulage times and evacuation times as well as the limit of working hours, the

vehicle drives through as many tours as possible and empty the corresponding containers.

c. The containers in the non-visited tours are not emptied and will be transferred to the next day's evacuation list.

The reason tours (vehicles) with higher utilized capacity are prioritized, is to collect as much waste as possible in-time as well as to utilize the capacity of the vehicles more efficiently.

4.2. Simulation

In order to evaluate the effect of sensors with respect to haulage cost and service level as well as to compare it with the current situation, we have employed computer simulation. In the simulation, two systems are compared: (1) the current system with static routing and (2) the system with sensors (where real-time levels of the containers are known) and dynamic routing. Both systems are given the same random values of daily waste for the containers to make them comparable.

4.2.1. Input data

The data consist of addresses, capacities (sizes) and evacuation frequencies of the containers, and are provided by the Agency for Waste Management. Further, distance between containers are calculated based on their locations. At first, the direct distances between containers have to be calculated. If two containers are adjacent, that is, directly connected to each other on a street, motorway or any other type of carriageway, without any other container in between, their direct distance is their distance on the corresponding carriageway. Such direct distances are obtained from Google maps ®. On the other hand, if two containers are not adjacent, their direct distance is infinite. After all of the direct distances are determined, the shortest distances between each two containers, henceforth called *distances*, are calculated by Floyd-Warshall algorithm (Floyd, 1962) as follows:

1. Let D_0 be the matrix of direct distances such that $D_0 = \left[d_{ij}^0\right]_{n\times n}$ where d_{ij}^0 is the direct distance between containers i and j and n in the number of containers.
2. If $i = j$ let $d_{ij}^0 = 0$.
3. For $k = 1 \dots n$ calculate the matrix $D_k = \left[d_{ij}^k\right]_{n\times n}$ as follows:

$$d_{ij}^k = \begin{cases} d_{ij}^{k-1} & , \quad if\ i = j, i = k\ or\ j = k \\ min\{d_{ij}^{k-1}, d_{ik}^{k-1} + d_{kj}^{k-1}\} & , \quad otherwise \end{cases} \tag{2}$$

4. $D_n = \left[d_{ij}^n\right]_{n\times n}$ is the matrix of the shortest distances between containers. In other words, d_{ij}^n is the distance (shortest distance) between containers i and j.

The above algorithm lets each container to come between each pair of the other containers to see whether it can reduce the distance between them or not.

Distances calculated by Floyd-Warshall algorithm are used as input to both static and dynamic methods.

When it comes to capacities, if two or more containers are placed at the same location, we assume that there is only one container whose capacity is the sum of the capacities of the corresponding containers.

AWM have also provided historical data about the evacuations of all of the containers during the period January 2011-April 2014. For each container, the data includes the date of evacuation and the level of the containers for each emptying. Fill rates are estimated based on these data. Since the fill rates are not fixed, a mean and a standard deviation is calculated for the daily fill rate of each container. If l_{im} and t_{im} denote respectively the level of container i and the number of days since the last evacuation at the mth time the container is emptied, then μ_i, the average daily fill rate, and σ_i, the standard deviation of daily fill rate, are estimated as follows:

$$\mu_i = \frac{\sum_m l_{im}}{\sum_m t_{im}} \tag{3}$$

$$\sigma_i = \frac{\sum_m t_{im} . |l_{im} - m.\mu_i|}{\sum_m t_{im}} \tag{4}$$

Values of μ_i and σ_i will be later used in simulation to generate random daily values of waste for each container.

Other inputs to the computer simulation are shown in Table 4.1.

Table 4.1 Constant inputs of the computer simulation

Constant	Value
Vehicles' speed (km/h)	17
Container evacuation time (minutes)	5
Container checking time below 10% (minutes)	1.5
Number of weeks in the simulation	56
Number of weekdays	6
Working hours per day	8
Vehicles' capacity (liters)	35000
Static evacuation proportion	10 %
Dynamic evacuation proportion	80 %
Service level base	80 %
Warm-up period (weeks)	4

Vehicles' speed is used to calculate haulage times. Container evacuation time is the time needed to check and empty a container. Container checking time is the time needed just to check how full a container is. When using the static method, if a container that is being visited is lower than 10% full, it will be checked (to find out how full it is) but not emptied. *Static evacuation proportion* denotes the minimum ratio of level of a container to its capacity in order to be emptied in the static method. Note that in the static method truck drivers first visit the containers and then, based the level of the containers, they decide whether to evacuate a container or not.

Similarly, *Dynamic evacuation proportion* denotes the minimum ratio of level of a container to its capacity in order to be emptied in the dynamic method. Note that in the dynamic method, in contrast with the static method, the level of the containers is first checked and then accordingly it is decided whether or not to empty them.

Service level base is the base of service level calculations. We have defined service level as the average proportion of days for containers where the ratio of level (end of the day) to capacity is not greater than the service level base. For example, if the service level base is 70% and there is only one container which is fuller than 70% in 2 out of 40 days, the service level is 95%.

We have executed the computer simulation for 56 weeks each of which 6 working days of 8 working hours. Of these 56 weeks, the first 4 weeks are considered as warm-up period. That is, the period needed for a simulated system to arrive into a steady (warmed-up) performance. Normally, performance measures of the system are not taken into account during the warm-up period.

4.2.2. Procedure of computer simulation

We have programmed the computer simulation in MATLAB® 2014b environment. A module in the program generates random values of waste (in liters) for each container, each day during a period of 56 weeks. These values are generated according to the mean and the standard deviation of the fill rate of each container by assuming that daily fill rate has a normal distribution. Values of daily waste are then added to the current level of the containers at the beginning of each day. Afterwards, in the dynamic method, the containers that are fuller than dynamic evacuation proportion will be added to the daily list of evacuation.

As for the static method, the weekly routes are generated before the simulation starts according to the algorithm explained in section 3 (nearest neighbor). The distances used to execute the nearest neighbor algorithm are calculated as explained in 4.2.1.

For both dynamic and static methods, levels of the containers at the end of each day (including Sundays), total haulage distance and capacity utilization of the vehicles in each tour are recorded.

5. RESULTS

The results or outputs of the simulation will be presented in two parts. In section 5.1.1, the static and dynamic methods are compared with respect to service level and haulage distance. In the next section, 5.1.2, we will see how the service level and haulage distance changes for the dynamic method when dynamic evacuation proportion changes.

5.1.1. Results of the simulation

A summary of the results when the dynamic evacuation proportion is 80% is given in Table 5.1.

Table 5.1 Comparison of the dynamic and the static methods

Output	Results
Total haulage distance - static method (km)	66876

Total haulage distance - dynamic method (km)	58924
Difference in haulage distance	-8,20 %
Average capacity utilization of the containers - static method	31,00 %
Average capacity utilization of the containers - dynamic method	39,40 %
Average capacity utilization of the vehicles per tour - dynamic method	84,50 %
Overload proportion - static method	1,70 %
Overload proportion - dynamic method	0,00 %
Service level - static method	97,10 %
Service level - dynamic method	99,10 %

According to the results, by using sensors and employing a dynamic routing algorithm, the total haulage distance during the last 52 weeks of the simulation (weeks after the warm-up period) is decreased by 7952 km or 8.2%. Furthermore, the service level is improved by 2.0%. That is, on average, in the dynamic method it is 2% less probable that a container is fuller than 80% than in static method. That probability for the dynamic method is only an impressive 0.9%. Moreover, there is no case of overloading in the dynamic method. *Overload proportion* is the average proportion of days where the level of a container is higher than its capacity. This is a highly undesirable case since it has a significant negative effect on customer satisfaction. Furthermore, the customers can complain and ask for immediate evacuation of the container which is overloaded. Comparatively, the static method has a 1.7% overload proportion that reflect a higher chance for customer dissatisfaction.

Interestingly, the results also show that the dynamic method utilizes the capacity of the containers better than the static method by 8.4%. That is because the dynamic method only evacuates the containers when needed, not sooner.

The only measure, according to which the performance of the dynamic method is not better, is the average capacity utilization of the vehicles per tour. The reason is that in the static method, the tours are made by emptying containers in the trucks until there is not enough room left for the next container. That happens when the truck is almost full. So, the capacity utilization of the vehicles are quite good. On the other hand, in the dynamic method, first, a daily list of containers is given. Then, the tours are generated such that the total haulage distance becomes minimized. Therefore, there might be more tours but with shorter total haulage distance in comparison with the static method. Nevertheless, this comparison shows that the dynamic method can operate the same system not only with shorter working hours or less capacity of vehicles but also with better customer service and shorter haulage distance.

5.1.2. Sensitivity analysis

In order to find a proper dynamic evacuation proportion, we have repeated the simulation for different values of dynamic evacuation proportion to make a sensitivity analysis on the aforementioned parameter. The sensitivity analysis makes it possible to trade off between

capacity utilization and haulage distance on one hand and service level on the other hand.

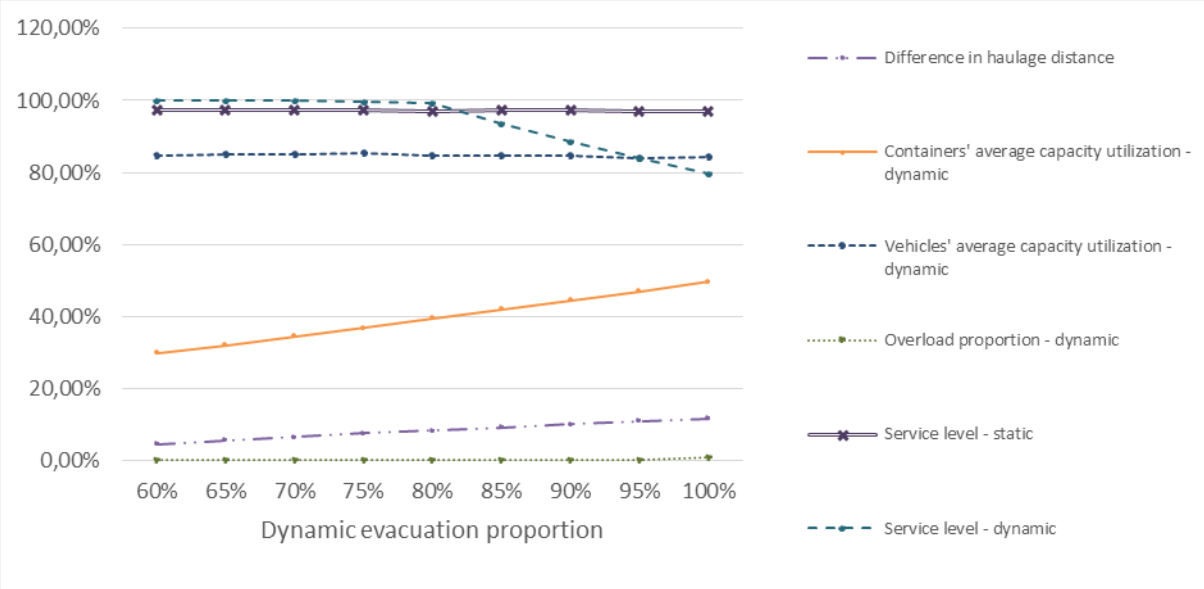

Figure 5.1 summarizes the results of the sensitivity analysis on dynamic evacuation proportion when it varies from 60% to 100%. Each time, we have increased the proportion by 5% and repeated the simulation over the same period of time.

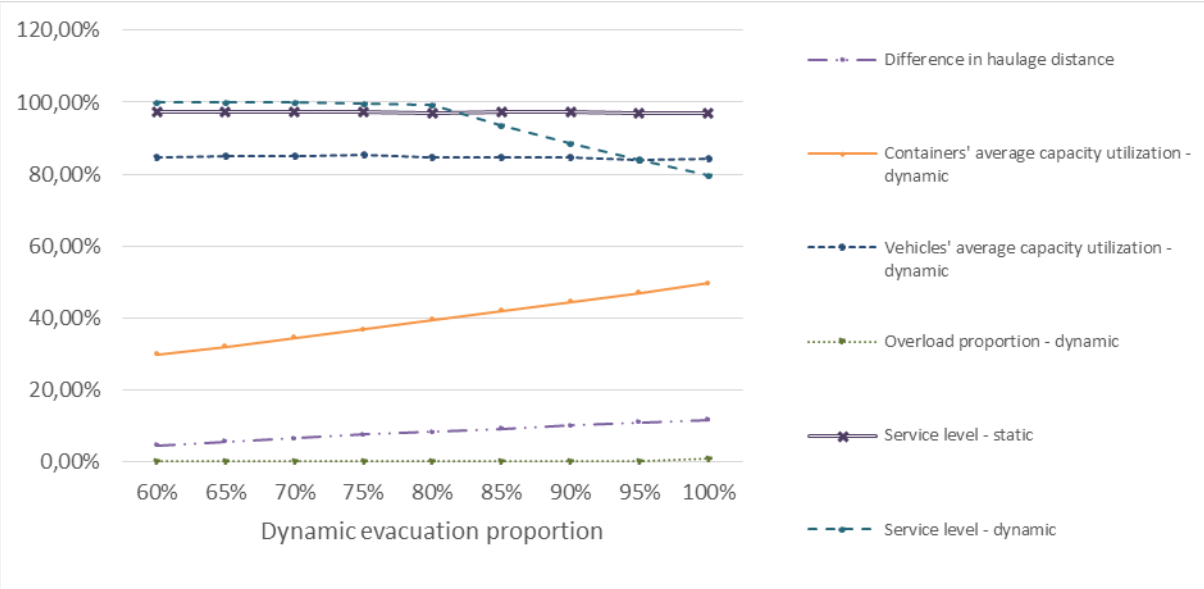

Figure 5.1 Sensitivity analysis over dynamic evacuation proportion

According to Figure 5.1 as dynamic evacuation proportion increases, the average capacity utilization of the containers increases. That is simply because the containers are emptied later (at higher levels). At the same time, difference between haulage distances of the dynamic and the static method increases. Since dynamic evacuation proportion has no effect on the performance of the static method, it means that the total haulage distance (dynamic method) decreases as the proportion increases. That is because the containers are emptied less often.

Nevertheless, increasing the dynamic evacuation proportion can lead to lower service level and higher overload proportion. As expected, we can observe that when dynamic evacuation proportion increases to 80%, the service level becomes slightly less than 100%, but it is still high enough. However, when we continue to increase the dynamic evacuation proportion even further, the service level drops significantly. After 95% the service level is even worse than that of the static method (which is independent of the dynamic evacuation proportion). Surprisingly, overload proportion is only higher than 0 when the dynamic evacuation proportion is 100%. That means the dynamic method can always effectively empty all of the containers in daily evacuation lists.

All in all, the initial 80% dynamic evacuation proportion shows a good balance between quality of service, haulage cost (distance) and capacity utilization. Therefore, it can be recommended to be used in practice.

6. CONCLUSION

Coming back to the theory of reverse logistics we have found that the use of sensors in waste containers is an effective way to reduce the quantity uncertainties, and that the dynamic algorithm is an effective way to reduce the timing uncertainties in the collection function. Also, the effect has increased service level and reduced haulage cost, which always is a gain in logistics systems. However, as reverse logistics systems is often an environmental measure in itself, these effects are even more powerful.

This paper presented a dynamic method to dynamically assign the containers to waste collection papers while using the real-time data of waste levels. A computer simulation showed that the performance of the proposed dynamic method is better than the current static system with respect to both haulage cost and service level. Therefore, it is likely that investment on the sensors pays off.

To continue this research it is worth to try other vehicle routing algorithms to obtain even shorter haulage distances and better vehicle capacity utilization.

ACKNOWLEDGEMENTS

We want to thank the Waste Management Agency from Oslo to provide the data for this research, and the Master students Katrine Lunde and Anett Cammermeyer for their work, and giving us the opportunity to continue with their work in our research.

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ECONOMIC APPRAISAL IN NORWEGIAN GAS TRANSPORT SECTOR

COST-BENEFIT ANALYSIS

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ABSTRACT

Purpose
The review of the investment planning and appraisal in the Norwegian gas transport sector shows that the currently used approach does not internalise all socio-economic impacts of a project on the concept selection phase. In this paper, a framework for economic appraisal of gas transport infrastructure projects, based on the methodology of Cost-benefit analysis (CBA), is suggested.

Design/methodology/approach
The regulatory framework for the investment planning in the Norwegian gas transport sector and impact assessments of selected infrastructure projects are analysed. The methodology of CBA is suggested in response to the revealed shortcomings of the existing practice. The main methodological aspects of the CBA application to gas infrastructure projects are discussed: the scope of analysis, stakeholders, relevant impacts, discount rate and uncertainty in the analysis. An example of a CBA with simulated numbers is provided.

Findings
In the existing appraisal practice, several problems may be highlighted: a concept is often chosen based on technical and financial considerations; an impact assessment is performed only for the chosen alternative; the analysis may be fragmented on different responsible parties. CBA offers a structural assessment, which allows for including the information related to financial considerations, network effects and social welfare in one framework, providing a ground for a direct comparison of alternatives.

Practical implications
This research is of interest for the Norwegian public decision-makers regarding gas transport infrastructure development.

Original/value
Originality if this paper is in the application of CBA to gas transport infrastructure projects. The paper can contribute to the improvement of the appraisal and decision making system in the Norwegian gas transport sector.

Keywords: Gas Transportation, Infrastructure, Investment planning, Impact Assessment, Cost-Benefit Analysis.

1. INTRODUCTION

This paper focuses on the investment planning and appraisal in the Norwegian gas transport sector. The natural gas infrastructure on the Norwegian continental shelf (NCS) is represented by a system of platforms, processing plants, receiving terminals and an extensive network of pipelines, with the total length of about 8000 km. This transportation network connects gas producers on the shelf of Norway with the end-users markets in Germany, Belgium, the United Kingdom and France.

Historically, investments in gas transport infrastructure have been made on the basis of financial analysis performed by investing companies and political considerations of the government. A complicated regulatory framework has been organized to ensure the involvement of the State at every stage of investment planning to balance commercial interests of companies with socio-economic considerations. The choice of a transport solution is a matter of negotiations between petroleum companies and authorities. Companies are interested in cost efficient and fast solutions. The authorities consider infrastructure development from the perspective of the long-term management of petroleum resources on the Norwegian continental shelf (NCS) for the benefit of the Norwegian society as a whole[1].

A relevant example of an infrastructure development is the ongoing discussion of a transport solution in the Barents Sea. According to the estimates provided by the Norwegian Petroleum Directorate (NPD), on average, about 35% of all undiscovered petroleum resources on the NCS are attributed to the Barents Sea (Ressursrapporten, 2013). The only transport infrastructure in the region available at the moment is the LNG (Liquefied Natural Gas) facility at Melkøya, which processes the gas from Snøhvit, the only field operating in that region (Figure 1.1). The operator of the field considers the expansion of the production and, accordingly, the expansion of the LNG facility. The main advantage of this solution is the market flexibility: a producer is not locked into the European market; the gas can be shipped by vessels to the highest value markets, implying higher profit. On the other hand, there is an option of a pipeline solution, connecting the Barents Sea with the existing transport network. The pipeline solution requires higher initial investments, lacks destination flexibility, but implies considerably lower than the LNG operating costs. Another benefit of the pipeline solution is the utilization of the transport capacity in the existing pipeline network, which may become spare in the near future. Maintenance costs for these transport facilities will be shared between larger volumes of transported gas, reducing the total unit costs. The most important advantage of the pipeline solution is a significant economy of scale in investments. There are low additional costs to establish capacity above the committed volumes, with regard to future discoveries and corresponding tie-ins. Available spare pipeline capacity in the transport system provides incentives for exploration in the region and reduces the cost threshold for development of deposits along the pipeline.

Compared to LNG facilities, investments in a pipeline infrastructure may generate significant value for the Shelf in the long run. However, such benefits of a pipeline solution may not be obvious for gas companies, which engage in infrastructure development projects only with the purpose of ensuring means to evacuate certain volumes of gas from their deposits. In addition, a pipeline and an LNG solution may have considerably different impacts on environment and nature, which may not be appropriately taken into consideration by petroleum companies. The socio-economic and project economic perspectives come in a conflict, when investors and authorities negotiate upon the concept choice for large-scale gas transport infrastructure

[1] Act relating to petroleum activities (the Petroleum Act), 29 November 1996, No. 72, Section 1-2.

projects. This conflict reveals itself in the approaches the parties use for a project evaluation: evaluated impacts, a timeframe of the analysis, calculation prices and a discount rate may differ considerably.

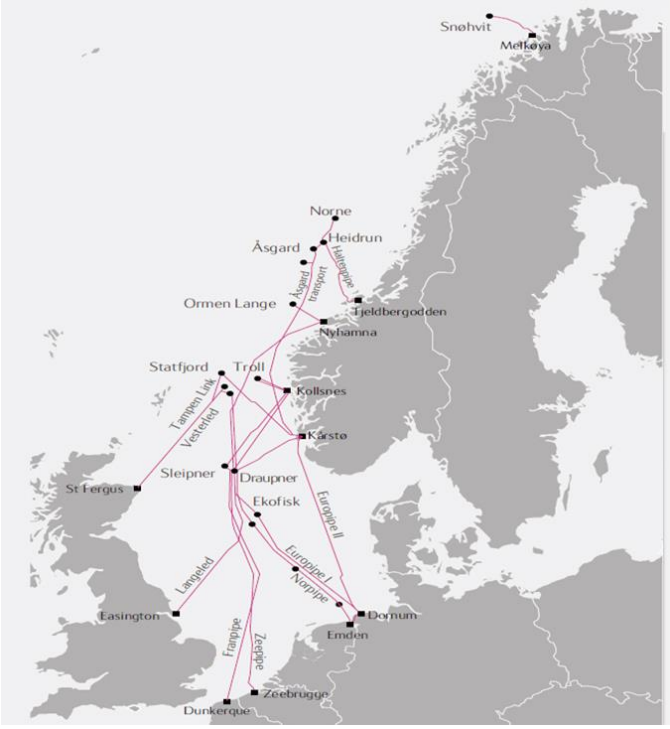

Figure 1.1 The map of the gas transport network on the NCS (www.statoil.com)

The review of the investment planning and appraisal in the Norwegian gas transport sector shows that the currently used approach does not internalise all socio-economic impacts of a project. The fact that an infrastructure project in the gas transport sector may have significant impacts on the parties other than the investors and potential shippers, calls for a wider evaluation perspective. In a response to the revealed shortcomings of the existing practice, a framework for economic appraisal of gas transport infrastructure projects, based on the methodology of Cost-benefit analysis (CBA) is suggested.

The paper is organized as follows. Section 2 presents a review of the relevant research. Section 3 considers the regulatory framework for the investment planning in the Norwegian gas transport sector and impact assessments of selected infrastructure projects. In Section 4, main methodological topics of CBA implementation to gas infrastructure projects are addressed, and a generalized example of a CBA is provided. Section 5 concludes.

2. LITERATURE REVIEW

A survey of academic literature on appraisal methodologies reveals relatively few examples related to the gas transport sector. In this respect, two issues may be highlighted: (1) a gas infrastructure development is usually a matter of private capital investments, therefore, the existing literature discusses evaluation approaches common in commercial decision-making; (2) petroleum companies regard an infrastructure development as a part of a field development, therefore the investment appraisal of the infrastructure project is usually not separated from the appraisal of the main project. There is a body of research within the decision theory, which focuses on investment decision-making in upstream oil and gas industry. Macmillan (2000)

investigates if there are links between the use of decision analysis in investment appraisal and decision-making by organisations and good business performance in the UK upstream oil and gas industry. Finch et al (2002) investigate to which extent formal and probabilistic appraisal and decision-making methodologies, like Monte Carlo simulation, are adopted by the private companies in the UK upstream oil and gas sector.

The only found research article, which addresses problems of appraisal practice in petroleum transport sector, is by Dey (2002). The author points out that, in project assessment in India, the optimum technical alternative is often selected using financial analysis; impact assessments are then carried out to justify the selection and subsequent statutory approval. Projects can be subjected to major revision or abandonment on the environmental ground, which incurs considerable costs to the company-operator of the project. This problem is addresses by developing a framework that integrates environmental impact assessment and socio-economic assessment into the project selection analysis by a petroleum company.

The problem of a concept selection on technical and financial grounds without an explicit socio-economic analysis is also relevant for the Norwegian gas transport sector. However, the focus of this paper is to consider investment planning and project assessment from the perspective of a public decision-maker, which aims to maximise total socio-economic value of an infrastructure project. Financial analysis, which is primarily used in private sector, aims to determine which outcomes are best from the point of private interests. Third party's affects are excluded from cost-revenue calculations. CBA, on its turn, is particularly designed for the evaluation of public projects, and all outcomes are evaluated on the basis of public interests.

The methodology of CBA is the most commonly used economic impact assessment approach for public decision-making in transport infrastructure appraisal (Vickerman, 2007, Mackie et al, 2014). Various examples include public roads investments (Salling and Banister, 2009, Damart and Roy, 2009), civil aviation (Bråthen et al, 2000, Jorge and de Rus, 2004), railways (Van Wee, 2007). Cost-benefit analysis has been a subject to criticism (see e.g. Nyborg (2014) for an elaborate discussion). One of the criticisms is that CBA is overly focused on economic efficiency and assigns monetary values for relevant effects to the extent possible, while not all impacts can be expressed in monetary units. As part of reaction to the criticism of CBA, multi-criteria analysis (MCA) has been suggested for economic appraisal. MCA is defined as a family of algorithms used to select alternatives according to a set of chosen criteria and their relative 'weights'. If CBA focuses on one unique criterion, the maximization of social welfare, MCA is a tool, which can comprise a set of different objectives, e.g. environmental impact, safety, economy, accessibility, and integration for road projects (European Commission, 2008). Both MCA and CBA aim at determining the consequences of a project on a society. MCA leaves it to the decision maker to make a trade off between the different criteria, while CBA solves this trade off explicitly by expressing all effects in monetary terms. Consequently, CBA is more suitable for answering the question of the project consequences on social welfare than MCA (Nooij, 2011).

Another reason for recommending CBA for project assessment in the Norwegian gas transport sector is the fact that Norway has a long history of successful implementation of CBA for economic appraisal within healthcare, transport infrastructure, public defence and other sectors (for discussion, see e.g. Nyborg (1998) and Odeck (2010)). The practical CBA-framework for national use has been provided by the guidelines by the Ministry of Finance (2000, 2005 and 2014), which are based on several Official Norwegian Reports: Green papers NOU 1997:27, NOU 1998:16 and NOU 2012:16 devoted to the methodology and application of CBA. In many sectors, the authorities provide sector specific guidelines.

3. INVESTMENT PLANNING IN THE NORWEGIAN GAS TRANSPORT SECTOR

The gas transport system on the NCS is a natural monopoly, owned by a group of commercial companies, represented by the Gassled joint venture, and operated by an independent system operator, Gassco, a state-owned company. In addition to the daily operatorship of the pipeline network, the system operator allocates available capacity among the eligible customers, charges tariffs and coordinates the expansion of the network[2]. The latter task implies the assessment of the need for additional capacity with respect to exploration results and demand forecasts. In its annual plans, the operator presents alternative solutions for the infrastructure development.

The planning of a particular transport facility is usually initiated by a group of companies holding licences for production of petroleum from the relevant area (Figure 3.1). Feasibility studies for the development of the fields are conducted in parallel to feasibility studies for a transportation solution. If the facility is planned to transport the gas from several fields (not a field-dedicated pipeline), a specific licence to install and to operate facilities for transport and utilization of petroleum is required (a pipeline licence). Granting a pipeline licence, the Ministry of Petroleum and Energy reserves a wide range of decisions for itself. The licence may be subject to conditions regarding ownership of the facility, the landing point of the pipeline, the routing, dimension and capacity of the pipeline[3].

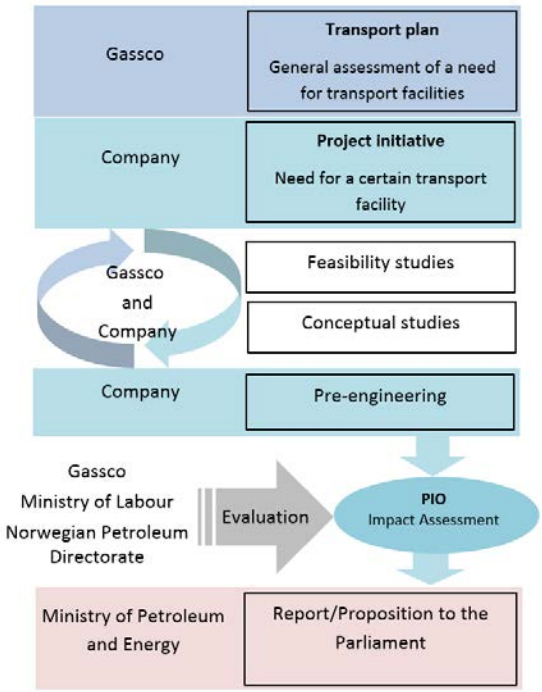

Figure 3.1 Gas transport infrastructure planning

The system operator Gassco is involved in the infrastructure planning at an early stage. The operator performs own assessments, makes recommendations regarding the technical aspects of an infrastructure facility (e.g. routing, landing points, capacity), but does not participate in

[2] Regulations to the Act relating to petroleum activities, 27 June 1997, No. 65, Section 66a.

[3] Regulations to the Act relating to petroleum activities, 27 June 1997, No. 65, Section 28.

investments and, therefore, cannot influence the investment decision (it is up to companies that finance a project to decide whether to apply for a pipeline licence). Circular arrows in Figure 3.1 depict the negotiations between the system operator and investing companies regarding the concept selection. When the concept is chosen, one of the involved companies is appointed as the operator of the project on the construction period. This company performs a pre-engineering and prepares the plan for installation and operation of facilities for transport and utilisation of petroleum (PIO), which represents the application for the pipeline licence. It includes an installation section and an impact assessment section. The installation section is devoted to the technical and financial aspects of the project, while the impact assessment focuses on the consequences of the project implementation (installation and operation) to the environment, natural resources, and the society in general. The basis for the impact assessment is the established study programme. The proposed study programme and the impact assessment itself are subject to a public consultation. Based on the installation section and the impact assessment as well as the consultation statements, the Ministry of Petroleum and Energy draws up a draft proposition to the Parliament or a Royal Decree, which is submitted to the relevant authorities (Ministry of Labour, Norwegian Petroleum Directorate and Gassco) for consultation. The matter is subsequently submitted by the Government either to the Parliament, or to the King in Council, depending on the size of the investment.

According to Section 29 of Petroleum Regulations, the PIO should, among other aspects, include "the criteria for the choices that have been made". The review of PIOs of several gas transport projects (table 3.1) shows that the criteria for the concept selection are related mainly to financial and technical aspects of a project.

Table 3.1 The criteria for concept choice of several gas transport infrastructure projects on the Norwegian shelf (as stated in the PIO)

Project	Alternative concepts considered	Criteria for concept choice
Tampen Link An export solution for the Statfjord field expansion (the North Sea). Started operations in 2007 A 32" pipeline, linking Statfjord field with the UK pipeline system FLAGS.	Export via a new pipeline to FLAGS (the UK transport system) and via the existing Norwegian pipeline system (50/50 distribution); Export of all gas via the existing Norwegian pipeline system; Export of all gas via a new pipeline to FLAGS; The use of the existing link to FLAGS and the Norwegian pipeline system.	Financial cash flow considerations: tariffs in the existing Norwegian pipeline system were higher than the investment cost of building a pipeline and the tariffs in the UK system FLAGS.
LNG Melkøya An export solution for the Snøhvit field (the Barents Sea). Started operations in 2007. An LNG facility at Melkøya, capacity 20 MSm^3/day, sea shipping to markets.	Only one alternative[4].	Not mentioned.

[4] Interestingly, in the PIO for the LNG Snøhvit (2001), a pipeline export solution was not mentioned among the alternatives, later in 2012, Gassco initiated a study of a possible major pipeline in the region.

Utsira High gas pipeline An export solution for the Edvard Grieg (the North Sea). Startes operations in 2015. A 16" pipeline, linking Edvard Grieg field with the UK pipeline system SAGE.	A pipeline, connecting the field to the UK pipeline system SAGE; A pipeline, connecting the field to the Sleipner platform and the Langeled pipeline (NCS).	Financial considerations.
Polarled A major export solution for several fields in the Norwegian Sea. Planned start of operation in 2016. A 36" rich gas pipeline from Aasta Hansteen field to the processing plant at Nyhamna, with tie-in for four minor fields.	*The landing points:* A new plant in Nordland The existing plant at Tjeldbergodden The existing plant at Nyhamna; *Connection to the existing export pipelines:* Åsgard and Langeled *LNG facility* (rejected at an early stage)	Technical aspects, incl. available capacity in the plants and pipelines; Market flexibility; Financial considerations.
Johan Sverdrup gas export An export solution for associated gas (3% of the flow) from the Johan Sverdrup field (the North Sea). Planned start of operation in 2019 A 18" pipeline, tied-in to a rich gas pipeline Statpipe, leading to the Kårstø processing plant	*The landing points:* Sage terminal in St. Fergus, Scotland FLAGS terminal in St. Fergus, Scotland Sleipner A platform (offshore) Kårstø plant.	Technical aspects of pipelines and landing points: lifetime, capacity; Financial considerations, incl. energy supply.

An impact assessment, included in a PIO, represents the analysis of the chosen concept in comparison with a situation where the project is not implemented. There are three main groups of impacts considered in all impact assessments: environmental impacts, impacts on natural resources, and impacts on the society as a whole. Most of the impacts caused by a pipeline, occur during the construction works and preparation of the pipeline to operation. Considered environmental impacts include emissions to air from installation equipment and vessels; emissions of cooling and ballast waters to sea during installation and spill of chemicals during cleaning and testing of the pipeline; effects on seabed (e.g. suspended sediment, levelling and stone filling to support the pipeline); impacts on landscape onshore (e.g. some parts of rocks may be removed in order to install the pipeline); impacts on sea flora and fauna (damage of corals by anchors, disturbed fish and sea birds); noise and light, garbage from installation works. Relevant impacts on natural resources are effects on fishery in the region: the fish fauna is affected due to the noise and physical activities in the area and the fishery itself may be restricted during the installation of a pipeline. Among the impacts on the society, the effect on the investment level on the Shelf, local and national supply of goods and services for the construction works, and employment are usually in the focus. Other considered impacts on the society include: possibilities for future offshore wind mills installations, restricted shipping in the area during construction, impacts to cultural heritage (traces of human activity from the period when the seabed was a dry land, rests of shipwrecks).

Major pipeline projects usually require either a construction of a new onshore plant or a modification of an existing one. In such cases, a separate impact assessment is performed. It includes the same three categories (environmental impacts, impacts on natural resources and impacts on the society), including, however, a wider range of effects. Construction of a facility onshore causes significant landscape impacts, may affect many animal species (otters, deer,

seals). Most importantly, a processing facility continues to have impacts after the construction period. Emissions to air are mainly connected to energy need, which may be covered by the electricity from the main grid or by a gas plant (the latter one causes significant of CO_2 and NOx emissions). Processing of gas causes continuous spills of wastewaters and cooling waters to the sea. The regional impacts are as well wider: an operating plant generates constant employment and supply of goods and services (as opposed to construction works), the load on the transport infrastructure increases, possibilities for recreation in the area may be reduced.

There is only one example of an impact assessment for an LNG solution on the Norwegian shelf – the LNG Snøhvit project. The chain includes a rich gas pipeline from the field to the processing plant, the plant itself, and the sea shipping. The approach to impacts assessment of an LNG solution and the range of evaluated impacts is the same as for a pipeline solution, with addition of the sea shipping part, which implies additional emissions to air and sea.

The approach of gas companies to impact assessment is determined by practical considerations: the consequences of project implementation are evaluated with respect to the compliance with the existing permits and rules and interests of the local authorities. Therefore, most of the impacts on environment and natural resources are evaluated qualitatively, only emissions to air are evaluated quantitatively. Based on the performed analyses for the impact assessment, some technical details of a project may be clarified, e.g. the exact route of the pipeline can be chosen such that possible conflicts with the shipping in the area are mitigated, or areas with corals are avoided. In the LNG Snøhvit project, the location of the plant in the Hammerfest municipality (the main two alternatives were the nearby islands Slettnes and Melkøya) was chosen based on such considerations as conflicts with shipping and available infrastructure. One of the mentioned reasons for the choice of the Melkøya location was a probability that a release for historical heritage on Slettnes could have not been granted by the local authorities. As the regional impacts is the main interest of the affected counties, the provided estimates mainly serve to prove that the project would have positive effect on the regional economy.

The critique of the investment planning and appraisal system in the sector may be formulated around to points. The first one is the concept selection. The fact that the system operator is involved in the feasibility and conceptual studies gives the reason to assume that the effects on the existing network and value creation on the Shelf are taken into consideration when the concept is chosen (the relevant reports are not publicly available). However, impacts related to the regional development, environment, and nature, do not come into the scope of the system operator's responsibilities. The assessment of these effects is left to commercial companies and is performed after the concept is chosen. The investment planning procedures are organised such that an explicit socio-economic analysis is required only within the scope of a PIO.

Another point of the critique relates to the approach to the impact assessment. As mentioned before, a pipeline solution usually requires expansion or construction of onshore facilities. Impact assessment for onshore facilities is performed separately from the impact assessment of a pipeline. As a result, an appraisal of one project may consist of several separate assessments, which may be performed by different parties, if the pipeline project and the processing plant are operated by different companies (the Polarled project is an example). The impacts in these separate assessments are tightly related to each other. For example, for a pipeline, emissions to air are usually estimated only for the construction phase, while for the operation phase, they are considered insignificant (only from vessels in connection to inspections and supplement dumping of stones and eventual reparations). However, the gas moves along the pipeline due to the pressure produced by compressors, which consume significant amount of energy, often produced by gas turbines. These compressors are installed at the pipeline entry, i.e. at a field or at a processing plant. Therefore, the emissions related to the transportation of gas are attributed to the facilities where the compressor is installed. The fact that the assessments are performed

by different parties, using different approaches, often restricts the comprehensive representation of a project consequences and may give decision makers somehow disintegrated information.

In order to eliminate the weaknesses of the existing investment planning and appraisal practice, there is a need for a methodology for a complete socio-economic analysis at the concept selection stage.

4. COST-BENEFIT ANALYSIS IN THE GAS TRANSPORT SECTOR

Though gas transport infrastructure investments are a matter of private funds, a permit/licence, given by the authorities, to develop a particular transport facility or a processing plant onshore may become decisive for the development of petroleum activities on the Norwegian Shelf in the long run and significantly influence the welfare of the Norwegian society. Gas infrastructure investments may have significant socio-economic consequences, which are not fully internalized in the appraisal at the concept selection stage.

A similar problem in the Norwegian public sector projects has been solved by the introduction in 2000 of the Quality Assurance (QA) Scheme for all public investment projects with a cost estimate exceeding NOK 750 Million. This scheme includes two external reviews in an investment project's planning process: QA1 – quality assurance of choice of concept, and QA2 – quality assurance of the management base and cost estimates before the project is submitted to the Parliament for approval and funding. A quality assurance of the concept selection (QA1) should include a CBA of status quo and of at least to alternative concepts.

However, state-owned companies with responsibility for their own investments are exempt from the QA Scheme. Relevant examples are infrastructure development decisions faced by the operators of the network of the Norwegian airports (Avinor) and of the main power grid (Statnett). The fact that these companies use their own funds, constituted by the user charges, for infrastructure development gives much stronger commercial aspect to their decision making then within the sectors with direct public funding. However, CBA plays and important role in their appraisal practice. These two sectors have market structures similar to the gas transport sector: they are represented by regulated natural monopoly transmission and transportation network segments and unregulated competitive downstream segments. The decision problem with respect to infrastructure development is also similar: to balance the network effects with the financial cash flow side of a project. Importantly, infrastructure projects in these sectors have significant externalities, that are not captured by a financial analysis, as travel time savings and environmental impacts. CBA provides a framework, which directly includes the external effects in the appraisal. The methodology of CBA can also be applied for economic impact assessment for gas transport infrastructure projects. In the next section, I consider in turn the main elements of CBA, defined by Boardman et al (2013), with respect to the application for project assessment in the gas transport sector.

4.1. CBA for gas transport projects – methodological topics

Scope of analysis. The purpose of a CBA in the gas transport sector is to measure the effects of a project for the Norwegian society as a whole. A change in a social welfare can be measured as a change in a social surplus. The change in the social surplus can be expressed by the following formula: $\Delta SS = \Delta CS + \Delta PS + \Delta GS$, where ΔSS is the change in a social surplus, ΔCS is the change in a consumer surplus, ΔPS is the change in a producer surplus, and ΔGS is the change in a governmental surplus. There is no effect on the consumer surplus in Norway, because most of the produced gas (98%) is exported. The change in the surplus of the government is determined by the spending of the government on a project and the received

income. There is no direct public funding of the infrastructure projects, therefore, there is no direct costs for the State. The revenue of the Government consists of the participation interest in the major gas producer Statoil (67%) and in the Gassled joint venture (45,8% via Petoro[5]), and corporate taxes. The revenue of the Government due to the participation interest is included directly in the change of the producer surplus. The corporate taxes may be either excluded from the analysis (if the revenue for the producers is counted before tax) or calculated as an impact to the State (if the revenue is counted after the tax). The main element of a CBA would be the change in the producer surplus. As opposed to a project-economic perspective, the effects of a new infrastructure development on the existing network should be included. This implies consideration of the effects on the following stakeholders: (1) Shippers in the new facility: gas companies, which are intended to ship the gas in the new infrastructure; (2) Investors in the project: companies that finance the development of the new transport facilities; (3) Shippers in the existing infrastructure; (4) Owners of the existing infrastructure (Gassled joint venture). In addition to the mentioned effects, gas transport infrastructure projects may have significant externalities, which occur due to market imperfections. Externalities are effects that production or consumption has on third parties – people not involved in the production or consumption of a good. In this case, these are environmental impacts, impacts on fisheries and shipping, and other real effects that have social value.

Set of alternatives. The definition of a base case is an important part of a CBA. The base case often represents the expected situation if none of the projects are implemented, a status quo. Because of the dependency of an infrastructure project on field developments, the status quo is often not viable. Certainly, companies may decide not to invest, but this decision will mean the termination of the deposit developments. Therefore, as the base case, the least costly solution can be taken, which will be most probably suggested by the companies, e.g. a pipeline solution with capacity exactly needed for the committed volumes or an LNG solution. Such definition of a base case requires a CBA of the initial solution as well. Alternative concepts may be related to the choice whether to process gas offshore or transport it onshore for processing (a rich gas pipeline), the choice of the landing point, the choice of an export solution: a dry gas pipeline or an LNG. It is important to mention, that not all of these decisions are confined in the scope of a PIO: e.g. in the Ormen Lange project, the decisions regarding the landing of gas onshore was included in the PDO, the PIO covered only the export pipeline Langeled.

Relevant impacts. For the shippers in the new facility the relevant impacts are the following: the cost of the use of infrastructure (pipeline transportation and processing) and the income from sales of dry gas and natural gas liquids (NGL). The pipeline transportation tariff[6] consists of a capital element and an operating element. The capital element is stipulated by the government, and is intended to cover the investment cost with a "reasonable" return on the capital invested (historically, 7% before tax). The operating element is calculated each year, and covers the operating cost of running a facility. If the new facility is connected to the existing export system on the NCS or the transportation system of other countries (e.g. the UK), the tariffs for the use of these pipelines should also be included. If alternative onshore processing facilities are considered, the eventual difference in the NGL recovery rate, and corresponding difference in the expected income, should be included in the analysis. If an LNG alternative is considered, it implies no fixed tariffs for transportation, but the operating cost for running the

[5] Petoro manages, on behalf of the government, the commercial aspects of the State's Direct Financial Interest (SDFI) in petroleum operations on the NCS and associated activities.

[6] Regulations relating to stipulation of tariffs, etc. for specific facilities, 20 December 2002, No. 1724

LNG chain. The LNG solution implies destination flexibility, which should be included as a price premium for the unit of sold gas.

The impacts to the investors are the investment costs and the expected income from the capital part of the tariff. In case of an LNG alternative, the facility does not become a part of Gassled, and the gas producer that invested in it operates and owns it by himself. The impact on the investor in the LNG is the investment cost only (the operating cost is counted as the cost of transportation for the shipper).

An inflow of gas from a new facility affects shippers and owners of the existing network. A higher volume of gas transported may reduce the unit cost of transportation, reducing the operating element of the tariff paid by shippers. The owners of the existing infrastructure may have income increase due to the inflow of new gas. Though the capital element is stipulated such that is should only cover the investment cost, it is usually set up before a facility starts operating for the whole licence period, based on the total investment costs and the expected volume of transported gas. Therefore, the investors can receive higher income if the volume transported increases (only if there is a significant change of the volume, the capital element may be adjusted).

The rest of the Norwegian society is affected through the externalities of gas transport infrastructure projects. The externalities are related to the environmental impacts. The cost of CO_2 may be partially included in the analysis through the respective taxes and allowances included in the operating costs. However, there is a differentiated tax structure in Norway: e.g. the carbon tax for oil and gas extraction is different from the CO_2 tax on petrol, while the agriculture and fisheries are exempted from this tax. It points on the fact that the taxes may not reflect the social costs of carbon. In order to compare alternative concepts with respect to their social costs, the estimates of total emissions are needed. Transportation of gas in the liquefied form includes extra processing steps (liquefaction and regasification) and a sea shipping, implying higher CO_2 emissions in comparison to the pipeline transportation. Alternative pipeline solutions may also have significantly different CO_2 footprints. Extracted rich gas has a certain CO_2 content, which may not meet the specification required by customers. In this case, the gas may be either cleaned during processing and the excessive CO_2 will be removed, or the gas may be blended in the pipeline system with gas from other fields, with a lower CO_2 content. The latter option generally implies lower CO_2 emissions. Other environmental impacts are not directly quantifiable. The landscape impacts, impacts on seabed flora and fauna, impacts on cultural heritage and recreation can be included in the analysis according to their existence values.

Among other relevant impacts, accident costs should be mentioned. There may be a failure in pipelines (a leakage), a failure in an onshore facility, an accident with an LNG ship. If an accident occurs, two main impacts can be identified: business losses and environmental damage (fatalities and injuries can occur, but are very rare). Material and administration costs are relevant to the investors, while negative impacts to the sea and air are related to the society.

Discount rate. The priced impacts need to be discounted by the social rate in order to calculate net economic benefits of a project. In the financial cash flow analyses performed by the companies in PIO's, a 7% discount rate is usually used. NOU 2012:16 Green Paper recommends to use a real risk-adjusted discount rate of 4% in a CBA for an ordinary public measure in Norway, for effects in the first 40 years, for the years from 40 to 75 – a rate of 3%, and a rate of 2% for subsequent years. The use of a social discount rate may significantly influence the outcome of the analysis: e.g. a discount rate of 7% nullifies the revenues to investors, as the expected rate of return on investments established by the regulated tariff is 7%; a lower discount rate makes it positive. However, it should be noted that the discounted rate for

the CBA of public investments includes a risk-premium only for systematic risks, connected to macroeconomic factors, while non-systematic risks, connected to the outcome of the specific project in question, are assumed to be diversified and the risk will be distributed over all taxpayers. For the gas transport investments, the non-systematic risk is a very important issue. For example, there is a very high uncertainty regarding the utilisation or pipelines in the long run, and an additional risk-premium may be reasonable. On the other hand, for an LNG alternative (if it is considered) the volume uncertainty is not relevant, as the LNG facility is planned exactly for the committed volume due to absent economy of scale in the investments. Different discount rates, reflecting different risk-premiums cannot be used to compare the alternatives. To handle the uncertainty related to the utilisation of the pipeline in the long run, a scenario analysis can be used. In practice, this is one of the main concerns of the system operator during the planning of a facility. In the next section, this decision problem is discussed.

4.2. Uncertainty in gas transport infrastructure projects

The expected production rate is a critical factor for decision making regarding the concept choice of an infrastructure solution, especially the capacity of facilities. It is determined mainly by two uncertain parameters: the gas prices and the rate of exploration success. Petroleum companies, planning an infrastructure, have in mind certain fields, with reasonably well defined resource volume. Therefore, dynamics of gas prices and potential contractual agreements determine the needed capacity of the transport facility. According to its architect role, the system operator takes a long-term perspective in planning and accounts for possible discoveries and future tie-ins in the system. It makes the exploration success the focal uncertainty factor for the system operator.

A case, when a capacity of a pipeline connecting a new area with the existing network (e.g. a pipeline in the Barents Sea) is considered. The tariff system on the NCS is arranged by zones. A new project of this type, most likely will comprise a new zone, with a tariff set up by the regulator independently from other transport facilities. The existing tariff system is mainly based on the rate-of-return regulation, which allows recovering of the investment cost. Therefore, the tariff can be approximated as a long-run average cost (LRAC) of transportation. The Norwegian gas transport system is a natural monopoly, facing increasing returns to capacity, which implies that the LRAC curve is downward-sloping (McCarthy, 2001).

The demand for transportation service (D) is driven by the demand for gas, which depends on gas prices. In the long run, it may be affected by the change of the European energy mix. Still, among the largest suppliers of gas to Europe (Algeria, Russia and Norway), Norway is usually regarded as the most reliable, meaning that with high probability the demand for the Norwegian gas will remain sufficient to market all produced gas.

An infrastructure project is initiated by gas companies in order to establish means to evacuate a certain volume of gas (a committed volume). In the planning horizon of gas companies, their demand for the transportation service is certain. In Figure 4.1(a), the short-term demand for the transportation service, D_0, is represented by a vertical line. Therefore, the gas companies propose a pipeline solution with a capacity C_0, corresponding to the committed volume V_0 – "alternative-0". This capacity implies $LRAC_0$ curve. The tariff would be set up at a level t_0. The system operator considers the new pipeline from a long-term perspective and takes into account possible new discoveries in the area, and proposes a solution with a capacity higher than the committed volumes. In the long run, the demand for transportation service is downward sloping: the transportation tariff will effect decisions to develop new fields in the area. However, the long-term demand is rather inelastic down to a certain tariff level, as for major and mid-size developments the tariff level may not be a decisive factor. Development of

marginal fields is more sensitive to transportation costs. Below a certain tariff level, the cost threshold for development of marginal fields is passed and the demand becomes more elastic.

Figure 4.1(b) depicts a situation where the system operator suggests a pipeline solution ("alternative-1") with capacity C_1 with regard to long-term demand D_1, which corresponds to a medium resource scenario. A solution with a higher capacity requires higher investment costs and implies a long-term average cost curve $LTAC_1$. In a short-term perspective, such a cost function means a higher tariff, t_1, due to the higher initial investment. However, if the medium-resource scenario occurs, the tariff is established at the level t_1^*, and the volume transported increases to V_1.

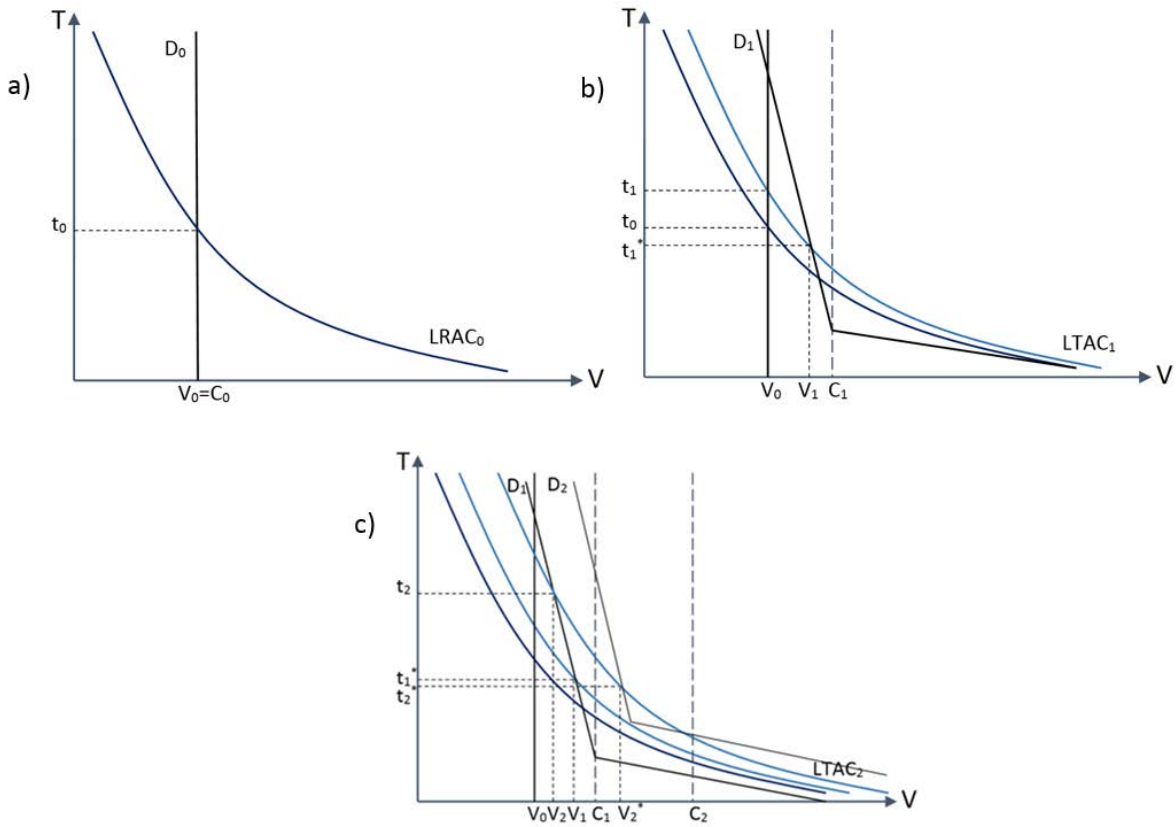

Figure 4.1 Demand, tariff level and volume transported

The system operator also considers possibilities of low and high resource scenarios. If the high resource scenario occurs, the capacity of "alternative-1" is not sufficient in the long run and a new transport solution may be required, or resource development may be postponed until the capacity of the established solution becomes spare, both outcomes mean welfare loss. Therefore, the operator considers a solution with capacity C_2 ("alternative-2"), which implies cost curve $LTAC_2$ (Figure 4.1 (c)). If there are significant discoveries in the area, the demand function shifts to the right and its elastic part begins at a higher tariff (meaning that in addition to large discoveries, there are many smaller deposits discovered with a cost threshold lower than before). If the second alternative was chosen, the new tariff, t_2^*, could be established at the first intersection of the demand function with the cost curve; the volume would then be V_2^*. However, the demand curve crosses the cost curve $LTAC_2$ again after the kink. Meaning that the tariff established at the intersection of the cost curve with the capacity limit would motivate to develop the marginal up to the transport capacity limit C_2. The problem with "alternative-2" is that is the medium resource scenario occurs, the tariff would be established at the level t_2, implying volume of transported gas V_2, which is lower than the corresponding volume V_1 if

"alternative-1" has been chosen. If there are no new significant discoveries in the area – a low resource scenario occurs – the demand for transportation service does not increase. In the long run, some of fields will finish operating, and the established infrastructure may become underutilized. In such circumstances, an LNG solution could have been preferable. As a public agency presenting the interest of the State, the operator aims to maximize value creation on the Shelf, which is directly related to the volume transported: the higher is the volume, the higher is the tax revenue, and overall economic activity on the Shelf. The presented figures show that the capacity expansion does not necessarily lead to maximisation of the throughput. However, a solution with excess capacity may be regarded as a solution with additional flexibility. Pre-investments in additional capacity provide opportunities to expand production in the future, if market conditions are favourable. Such flexibility may have significant value in the long run, which should be weighted upon the tariff increase due to a higher investment cost. This approach calls for the use of quasi-option values in a CBA: the value of flexibility should be added to the benefits of the solution with excess capacity. In the next section, I show how these values can be incorporated in the analysis among other impacts.

4.3. A CBA example

Table 4.1 presents a general structure of a potential CBA with simulated, but realistic, numbers for the concept selection for a large-scale infrastructure project in the gas transport sector.

Table 4.1 Example of a CBA with simulated numbers (Million NOK, 4% discount rate)

	LNG	**Pipeline X"**	**Pipeline 1,2X"**
Shippers in the new infrastructure			
Revenue (excl. production cost)	9000+500	9000	9000
Tariff in the new infrastructure		-6500	-7000
Tariff the existing network		-1000	-1000
Cost of shipping	-4500		
Investors in the new infrastructure			
Pipelines		-4000	-4300
Expansion of onshore facilities	-3000	-2000	-2100
Tariff revenue (capital element)		6100	6500
Shippers in the existing infrastructure	0	150	150
Owners of the existing infrastructure	0	800	800
Subtotal for the Shelf	**2000**	**2550**	**2050**
Option value of flexibility provided by excess capacity			2000
The rest of the society			
Social cost of CO_2 and NO_x	-1200	-800	-900
TOTAL	**800**	**1750**	**3150**

Considered example represents a case similar to the Barents Sea Infrastructure Project: there is an LNG facility that can be expanded, and two alternative pipeline solutions: one with a capacity exactly needed to transport the committed volume and one with a capacity 20% higher

with regard to possible future tie-ins; both pipeline alternatives require expansion of onshore facilities. At the initial stage of the analysis, the committed volume of gas is the same for all the alternatives; however, the expected revenue for the LNG alternative is higher due to the destination flexibility. Due to the difference between the rate of return on the investment (7%) and the social discount rate (4%), the net income for investors in the pipelines is positive. The inflow of new gas into the existing network brings additional income to its owners and reduces operating element of the tariff for the shippers. Considering the cash flow only for the producers/shippers in the new infrastructure, the LNG alternative is preferred. From the perspective of the Norwegian Shelf as a whole, both pipeline solutions are better. Taking into consideration only the committed volumes, the alternative with excess capacity has the same revenues, but implies higher costs. However, if the value of flexibility provided by the excess capacity is taken into account, the third alternative has the highest value. Monetized impacts on the rest of society according to the social costs considerably affect the values of the net economic benefit of the alternatives. For the projects where the expected NPVs of alternative solutions are closer to each other, these impacts may become decisive.

To perform a CBA in real settings may be a challenging, but executable task. The calculation of total impacts on the investors and shippers in the new infrastructure is a straightforward task, as these numbers are presented in the PIO. The impacts on the owners of the existing network can be estimated as a product of the gas volume coming from the new pipeline and the tariff in the existing system. The calculation of the impacts on the exiting shippers due to reduced operating element of the tariff is a demanding task, which, nevertheless, can be accomplished by the system operator. In order to estimate the value of flexibility provided by excess capacity, a real options approach can be used. In order to monetize the external effect of carbon emissions, the calculation price of carbon provided by the authorities should be adjusted by the costs already paid by gas companies through taxes and relevant permits.

5. CONCLUSIONS

In the study of possible infrastructure solutions in the Barents Sea, the gas transport system operator Gassco states the following: *"Identification of possible measures to bridge the gap between socioeconomic and project economic perspectives should be a focus area in near-term. Clarifying these issues will enable the industry and the authorities to make informed decisions to maximize the value of the Barents Sea resources and to secure alignment with decisions that are taken in the existing system"* (Gassco, 2013).

The implementation of CBA for the evaluation of gas transport projects may become one of the measures to improve the appraisal system in the sector. The decision problem in the gas transport infrastructure development has three levels: financial considerations of gas producers and investors, effects on the existing network and future development of transportation system, and impacts on the rest of society. The methodology of CBA can provide a framework to put these three aspects on the same scale and explicitly estimate net social benefits of relevant alternatives and provide a sound decision support.

Introduction of CBA does not require any structural changes of the established planning and appraisal procedures; it can be rather regarded as a missing link in the investment planning. However, a practical implementation of CBA requires substantial theoretical work, such as elaboration of methods for consistent estimation of environmental impacts and impacts on natural resources, methods for valuation of flexibility in investments.

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RELATIONSHIP BETWEEN TANKER FREIGHT RATES AND OIL PRICES: STRUCTURAL ECONOMETRIC MODELLING

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ABSTRACT

In a nearest future new hydrocarbon fields have to be developed and it seems Arctic deposits have to be explored more and more intensive. Large-scale studies in different economic spheres ("Arctic angle") in some countries already started. The expedience of North Sea Route using to transport crude oil, gas-condensate and natural gas is evident. Logistics has to offer new and well-founded solutions for transport sector. According to the information appeared recently oil and gas production in Arctic has to be at the level of millions of tons. So the possibility of tanker freight market formation or linear shipping is an item which should be studied. Taking into account quite high raw material production cost the link between oil price and transportation costs has to be studied with attention. Analyses of this link and creation of forecasting models could help the evaluation of logistic costs. The purpose of this study is to investigate the relationship between fluctuations in oil prices and the freight market using structural econometric modelling in particular methodology and tools with applications under EViews. The demand for crude oil/petroleum products transport services is a derived demand, which is dependent on international trade of crude oil and crude oil tanker transport from producer regions to consumer regions. Transport costs are one of the most important components of crude oil final price. It is important to evaluate all logistic costs to predict the final cost of crude oil in the port of final destination. The study effectuated by us analyzes the impact that spikes in oil prices have on tanker freight rates. The effectuated study contains different data of main tanker routes of different size groups of tankers specially Suezmax, VLCC and ULCC as Middle East – Far East, Middle East - West Europe. The study also presents different versions of freight indexes and oil prices relations. Our findings show a relationship between spot and future crude oil prices and tanker freight rates but models used have to be developed. In a real practice the better knowledge of the relationship between freight rates and crude oil prices can improve operational management, planning and financial decisions.

Keywords: Crude oil, transportation, tanker freight rates, economic modelling, crude oil prices, tanker freight market.

INTRODUCTION

Crude oil and petroleum products are commodities traded on global markets. The demand for crude oil/petroleum products transport services is dependent on international trade of crude oil, location of oil production fields and refineries, availability of tanker fleet and other factors. Transportation costs are one of the most important components of crude oil final price. It is important to evaluate all logistic costs to predict the final cost of crude oil in the port of final destination.

Russia started creating a new industrial base in the Arctic region and many new logistic technologies have to be developed. There is no infrastructure and in the Arctic. Traditional approaches of logistics based on an intensive use of infrastructure (roads, warehouses, information streams, etc.) in the conditions of the Arctic don't work. A lot of things should be started from scratch. One of important tasks is the efficient exploration of North Sea Route including for hydrocarbon transportation. Some new capacities appeared recently as new port Sabetta. New ice-class tankers were constructed and new ship-building capacities for icebreakers were put in operations.

Active exploring of North Sea Route and intensive tanker operations will set the task of the organization of transport services - tramp or liner. Companies of course will have possibility to organize their own crude oil transportation using own ice-class tankers. In “Gubkin” University some studies of different Arctic topics have started. At the first stage some studies regarding links between oil prices and transportation costs on the main crude oil international routes were made. Below only a part of studies is presented. Of course such routes as Persian Gulf – Japan or Persian Gulf – Europe differ from North Sea Route. But available data base as crude oil price and tanker freight rates helped to create more or less suitable models.

1. A REVIEW OF STUDIES CRUDE OIL PRICE-FREIGHT RATES

Arctic oil and gas topic papers describe in general the onshore and offshore exploration and development, the existing of significant volumes of oil and gas discovered, operational risks, the challenges facing future oil and gas exploration and development in this cold and remote region, a range of future production forecast scenarios. In “Working Document of the NPC North American Resource Development Study, 2011” Arctic Subgroup says: “These discoveries (in the Arctic) have yet to be produced due to lack of development and production infrastructure, including pipelines, because they have been unable to compete economically with alternate oil and gas sources”.

Arctic oil and gas is on the agenda of non-arctic countries. Some logistical items were touched upon by Eiji Sakai (2013) in “Development of Japan Policy Toward Arctic Ocean” the Author proposes promptly respond to logistical changes in the seaborne trade by the opening Arctic Seaways.

Publications concerning links between oil prices and tanker freights presented in different journals and monographs for last 55-60 years. The development of world petroleum industry – drilling, extraction, refining, distribution – also world maritime fleet, port infrastructure, pipeline systems and many other factors arise a problem of reduction the share of transportation costs in a final oil price. Well known economic rule/low “supply – demand” as a base to determine (more or less) price trends in conditions of existing of many political, economic, social factors (which are not “frozen” and in different regions have different influence) is difficult to apply directly/frontal.

Platon M. Velonias (1995) has studied topics concerned tanker fleet size groups used to serve different routes. Some results of quantitative analyses concerning the freight rates for ship sizes 40 000 – 70 000 dwt in the routes on studied destinations is heavily dependent of the employment of the larger sized group (200 000 – 300 000 dwt) could be used for Arctic conditions.

Studies of links between oil prices and tanker freights were made by many researches and analytical centers. Ex., UNCTAD has published in April 2010 quite detailed report concerning this item. In this report many significant publications were analyzed and quite clear picture of the subject was offered. So in the study by Poulakidas and Joutz (2009) (which is often cited) the impact of the spike in oil prices on tanker rates was analyzed. They demonstrate the close relationship between spot and future crude oil prices, crude oil inventories and spot tanker rates. In their publication (p.3. Econometric Modeling Issues) authors "employ the general-to-specific modeling approach… which is a relatively recent strategy used in econometrics". In the four steps of analyze they exam "the time series properties of the individual data series... then authors form a Vector Autoregressive Regression (VAR) system … then they exam the system for potential co-integration relationship(s) and finish with interpretation the co-integrating relations and test for weak exogenerity". In Conclusion part of the article authors say:".. we are able to uncover a demand relation for tankers in the spot market using co-integration analysis. This finding may reflect the idea that the demand for tankers is a derivative for the demand for oil. If there is a strong demand for oil, there is a strong demand for tankers so it is possible for tanker companies to raise rates". It's necessary to stress that above mentioned model authors studied only for the tanker route West Africa – US Gulf. This route is not so complicate as for ex. Persian Gulf – Far East (Malacca) or Persian Gulf – North Europe (straights, channel etc.). On that routes many different factors are played including "pirate factor" (insurance etc.).

In OECD study "Clarifying Trade Costs In Maritime Transport" the following factors are analyzed and discussed – Distance, Time, Trade Imbalances, Trade Volume and Vessel Size, Competition, Infrastructure, Piracy And Other Risk. We consider as important the following conclusion of the Study (page 17, p.47) – "No calculations are made in this study to estimate data for transport costs of tankers which are used in their vast majority to transport petroleum products. Although petroleum and petroleum products are important commodities in terms of both value and volume shipped, the tanker segment of maritime transport is subject to particular practices. Petroleum is generally traded on the spot market while in transit. The captain of a tanker fully loaded with oil from the North Sea, for example, often does not know where he/she is going when heading off to sea. The tanker may change course numerous times during its journey as its contents are bought and sold on the spot market. It is also assumed that there is no substitution effect of tankers with the other segments of the maritime transport industry (containers, "clean bulk" or "dirty bulk")". OECD study nonetheless estimated an elasticity of freight rates to oil prices ranging from 0.018 to 0.150. But this elasticity is more or less familiar to other cargo and not to crude oil.

In different other studies experts estimated elasticity of ocean cargo costs in function of fuel prices between 0.232 – 0.327 (Hummels), and 0.088 – 0.103 (Mirza and Zitouna).

In 2010-th many research papers have analyzed the effect of high crude oil prices over the functioning of different segments of economy. Also some experts analyzed the impact of crude oil prices and seaborne trade. So D. von Below and P.-L.Vezina say in their article "… that persistently-high oil prices may indeed put the breaks on globalization as the distance elasticity of trade is higher in years of high oil prices. What we find is that a large increase in the price of oil, from 100$ to 200$, is akin to imposing a world-wide tariff of between 4% and

9%, the higher the longer the distance between countries." They show that low oil prices reduce the distance elasticity of trade. To identify the effect of oil prices on trade Authors used the gravity model of trade (Anderson and van Wincoop, 2003).

Crude oil prices in the Arctic oil fields according to existing hypothesis will not be low. In this connection a study made by Maritime Administration of US Department of Transport (2008) is interesting because some original approaches for modelling and impact of oil price on transportation.

For better estimation of the real situation turned out in 2014-2015 with oil prices and its impact with tanker freight we consider to make a short review of freight market. Low crude oil prices come to the aid of the shipping sector because a higher demand for oil tankers. The Baltic Dirty tanker Index and the Baltic Clean Tanker Index which are indices for freight rates to transport crude oil and petroleum products have rose by 44% and 53% at the end of 2014. Of course, a part of experts says lower oil prices make oil purchases very attractive.

Well known from different statistical sources the world maritime fleet during I-III Q of 2014 rose by 1% by 4.9 million dwt. Majority vessels are product tankers. Crude oil tanker fleet rose by 0.3% or 1.1 million dwt. Among them VLCC fleet rose by 7 vessels and number of Suezmax reduces by 2 vessels and Aframax by 13 vessels. According to shipyard news the global tanker fleet has to increase by 2%.

Interesting positions were published by experts from Teekay Tankers Ltd.(teekaytankers.com) and HIS Maritime 360 (ihsmaritime360.com). Represents of the tanker company say the increase in tanker rates was primarily due to a combination of stronger seasonable oil demand in July and August, an increase in long-haul crude movements from Atlantic to Pacific and an increase in oil purchases for onshore commercial and strategic storage. Experts say that the strength in tanker rates is in part due to the impact of lower oil prices, which is having a positive impact on tanker rates in a number of ways. So lower prices encourage stockpiling of crude oil. For ex., China has to promote the second phase of Strategic Petroleum Reserves Plan. Contango price for crude oil encourage buying of crude oil. Low bunker prices encourage ship-owners to earn more from operating cost. And others.

IHS Maritime touched upon the situation also with tanker fleet and said a substantial number of VLCCs being booked for floating storage and higher condensate exports from the US. In 2015 VLCC fleet growth could be 27 vessels while 15 VLCCs would be aged 20 years and older. Oil demand this year is estimated to grow 2.1% and more oil will be imported for restocking. They say 17 VLCC have been booked for floating storage by oil majors and traders. According to HIS Maritime "Long-dated crude oil futures are increasingly priced higher than spot crude oil prices tanked in September, 2014, resulting in a price contango. As the contango increases, traders and oil producers will be further incentivized to store current oil production for future sale, hence hiring more VLCCs as offshore oil storage. The employment of VLCCs for storage effectively could tighten supply for transportation purposes, leading to stronger freight rates."

Our own opinion is following. Of course, while crude oil prices are going down bunker prices also have to go down and this fact is real. On the bunker market prices are smaller comparing the previous period. Logically the scheme "low crude price – low freight" could be real. But general situation is presented in the table 1.1.

Table 1.1.Average freight rate in USD per day single voyage and oil price USD/b

	2012	2013	2014
VLCC	20900	17600	29200

Suezmax	14700	14100	26100
Aframax	15400	16300	23200
LR2 Prod.	14300	13500	18700
MR2 Prod.	13000	16300	11500
Oil Price	111.95	108.84	98.94

Source: The Platou Report 2015. P.17.

As the table data show while crude oil prices during three years decrease freight rates increase.

Taking into account different results of researches effectuated by experts, expert groups and organizations we consider the following. Freight rates are in function of a number of factors and operation only with 2-3 factors doesn't permit to obtain quite convincing forecasts. Based on different studies (here we mentioned only 4-5 publications) the following key factors have to be taken as a base to forecasting tanker freight rates:

- Crude oil prices
- Changes in regional and world supply-demand balances for short-mid-long period
- Influence of different political, civil, natural factors (as the war, strikes, hurricanes)
- Seasonal and climate changes
- Inventory, oil depot, oil port terminals etc. factors
- Policy of National oil Companies
- New oil discoveries
- Refinery policy (incl. technical stops etc.), appearance of new capacities
- Balance of new tankers and tankers for scrap
- Decisions to use tankers for oil stock
- Regulations and public policy.

2. DATA USED AND ECONOMETRIC MODELING

For analyzes we took tanker freight rates for the route Persian Gulf – Japan for VLCC/ULCC vessels for the period from 2000 to 2014. Also we took into consideration crude oil Europe Brent (USD/t). Spot crude oil price were taken from data base of Energy Information Administration (EIA).

Table 2.1. Freight rates for the route Persian Gulf – Japan, WS, USD/t

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	55	62	50	46	50	50	48	138	150	146	170	155
2001	116	80	75	69	42	42	81	84	84	56	45	39
2002	45	30	30	45	56	56	40	32	50	62	85	110
2003	126	110	130	84	70	89	89	49	100	80	109	148
2004	89	89	100	120	135	135	130	122	109	200	270	256
2005	74	120	103	87	57	57	90	60	100	134	167	126
2006	110	104	83	56	74	101	112	120	109	69	68	58
2007	58	59	82	50	81	63	63	56	54	57	71	195
2008	122	96	97	109	212	20	23	84	105	81	57	66

						4	8					
2009	51	44	41	27	27	46	42	40	33	43	44	56
2010	104	71	84	90	72	95	58	51	48	47	75	61
2011	48	74	63	50	51	54	50	48	45	50	57	59
2012	67	52	59	63	63	44	36	35	38	37	41	48
2013	43	33	34	33	38	38	38	40	40	50	45	62
2014	73	60	55	40	40	40	32					

Then we present data for crude oil spot prices in table 2.2.

Table 2.2. Crude oil prices, USD/t

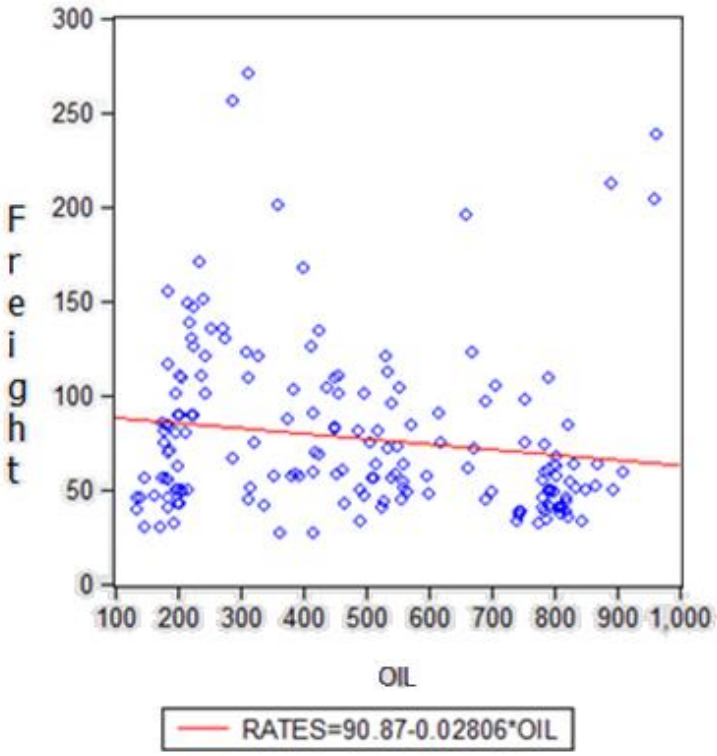
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
2000	185,5	202,0	199,9	165,5	201,7	216,7	208,6	219,6	241,0	225,1	236,7	186,6
2001	186,3	200,0	178,2	186,6	205,9	202,5	179,0	186,7	186,3	149,4	136,7	136,1
2002	141,2	147,5	172,3	187,1	184,3	175,1	187,2	193,8	206,5	200,3	177,0	206,0
2003	226,7	238,3	222,6	181,8	188,0	201,1	206,2	217,4	197,1	215,3	209,1	216,8
2004	227,5	224,4	244,5	244,3	273,2	255,8	277,9	310,8	314,1	362,0	313,5	288,0
2005	323,7	330,7	386,1	377,3	353,8	395,2	418,3	465,2	457,5	425,7	401,7	413,5
2006	458,0	437,8	451,3	510,9	507,4	498,5	535,7	532,5	450,6	420,4	427,3	454,3
2007	390,3	418,6	451,2	490,8	488,7	516,7	559,4	514,5	561,2	598,8	672,0	661,2
2008	670,3	690,7	753,6	793,1	893,0	962,2	965,1	823,4	707,0	520,5	381,4	290,5
2009	315,9	315,0	338,4	364,9	416,7	498,9	468,6	527,3	491,9	529,2	557,4	541,5
2010	553,9	536,3	573,2	616,8	552,3	543,6	549,6	560,2	566,0	601,2	620,1	665,0
2011	701,9	754,2	833,6	896,3	836,2	827,7	850,6	801,5	820,5	796,6	805,5	784,4
2012	804,9	867,7	912,2	870,8	802,4	692,0	746,2	824,3	820,7	812,3	793,1	796,2
2013	821,4	843,9	788,8	743,5	745,8	748,4	784,8	809,2	811,5	793,2	783,8	805,4
2014	786,2	791,9	781,6	783,6	796,5	813,0	776,4					

Data from both tables were used in Eviews. There were two series of data – FREIGHT and OIL.

Table 2.3.Statistics of two variables FREIGHT and OIL

	Freight	Oil
Mean	77.30286	483.5946
Median	62.00000	458.0444
Maximum	270.0000	965.1000
Minimum	27.00000	136.0535
Std. Dev.	44.01678	246.4018
Skewness	1.828178	0.211287
Kurtosis	6.998969	1.636381
Jarque-Bera	214.0884	14.86061
Probability	0.000000	0.000593
Sum	13528.00	84629.06
Sum Sq. Dev.	337120.9	10564208
Observations	175	175

These data could be introduced in a graph. See graph. 2.1.



Graph 2.1. Correlation field FREIGHT – OIL.

Then we present matrix of correlations without data for December 2008- November 2009 because of economic crises – table 2.4.

Table 2.4. Correlation matrix

	Freight	Oil
Freight	1.000000	-0.361487
Oil	-0.361487	1.000000

And then we present results of ADF – test for each variable.

Augmented Dickey-Fuller test statistic		-13.31792	0.0000
Test critical values:	1% level	-2.579587	
	5% level	-1.942843	
	10% level	-1.615376	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(FREIGHT ,2)
Method: Least Squares
Date: 12/14/14 Time: 17:46
Sample (adjusted): 2000M03 2014M07
Included observations: 159 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(FREIGHT (-1))	-1.057685	0.079418	-13.31792	0.0000

R-squared	0.528872	Mean dependent var	0.088050
Adjusted R-squared	0.528872	S.D. dependent var	38.23154
S.E. of regression	26.24166	Akaike info criterion	9.378843
Sum squared resid	108802.7	Schwarz criterion	9.398144
Log likelihood	-744.6180	Hannan-Quinn criter.	9.386681
Durbin-Watson stat	2.027105		

Figure 2.1. ADF test for FREIGHT

Then the same for Oil.

Augmented Dickey-Fuller test statistic		-11.32335	0.0000
Test critical values:	1% level	-3.471719	
	5% level	-2.879610	
	10% level	-2.576484	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OIL_2008,2)
Method: Least Squares
Date: 12/08/14 Time: 14:13
Sample (adjusted): 2000M03 2014M07
Included observations: 159 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(OIL_2008(-1))	-0.916968	0.080980	-11.32335	0.0000
C	5.363470	2.614798	2.051198	0.0419

R-squared	0.449544	Mean dependent var	-0.032928
Adjusted R-squared	0.446038	S.D. dependent var	43.55730
S.E. of regression	32.41909	Akaike info criterion	9.807871
Sum squared resid	165006.6	Schwarz criterion	9.846473
Log likelihood	-777.7257	Hannan-Quinn criter.	9.823547
F-statistic	128.2182	Durbin-Watson stat	1.951172
Prob(F-statistic)	0.000000		

Figure 2.2. ADF test for OIL

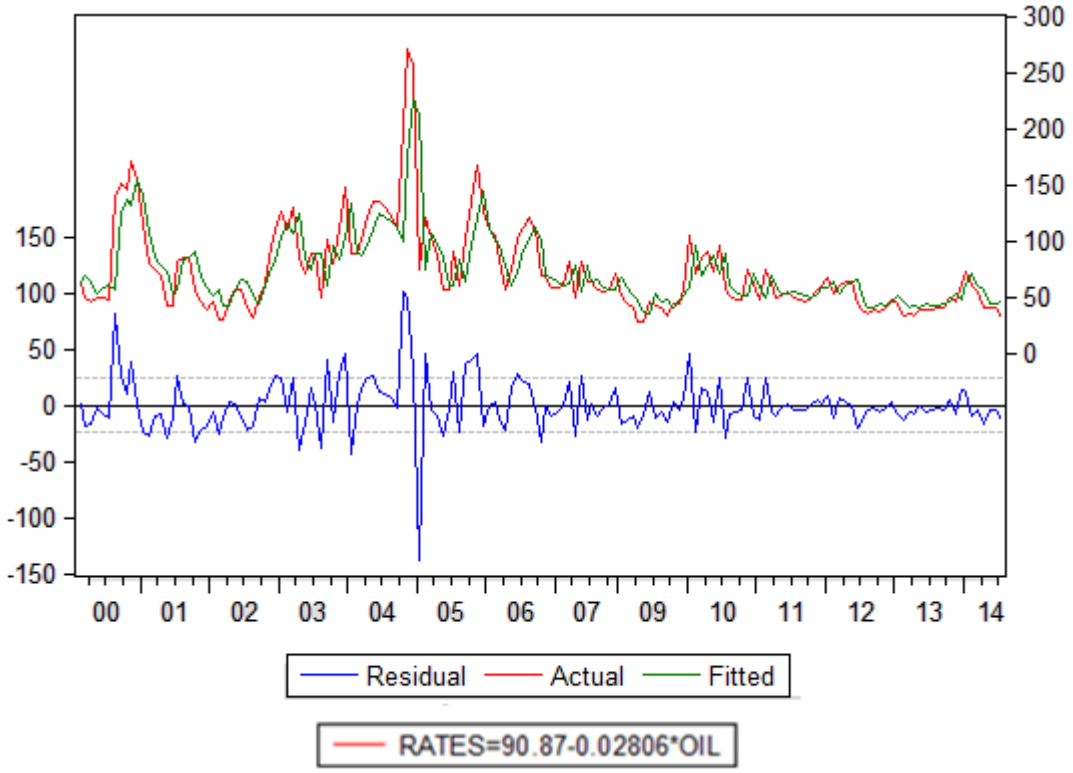
Then correlations for Freight and Oil were made. On the following figure data are presented.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.058	-0.058	0.5435	0.461
		2	-0.151	-0.155	4.3104	0.116
		3	-0.083	-0.105	5.4677	0.141
		4	-0.010	-0.049	5.4847	0.241
		5	-0.083	-0.122	6.6302	0.250
		6	-0.118	-0.164	9.0008	0.174
		7	-0.001	-0.076	9.0009	0.253
		8	0.014	-0.074	9.0333	0.339
		33	-0.042	-0.029	29.164	0.659
		34	0.029	-0.005	29.343	0.695
		35	0.027	0.003	29.490	0.731
		36	-0.049	-0.070	29.994	0.749

Figure 2.3. Correlation for Freight

The same correlation was made for Oil.

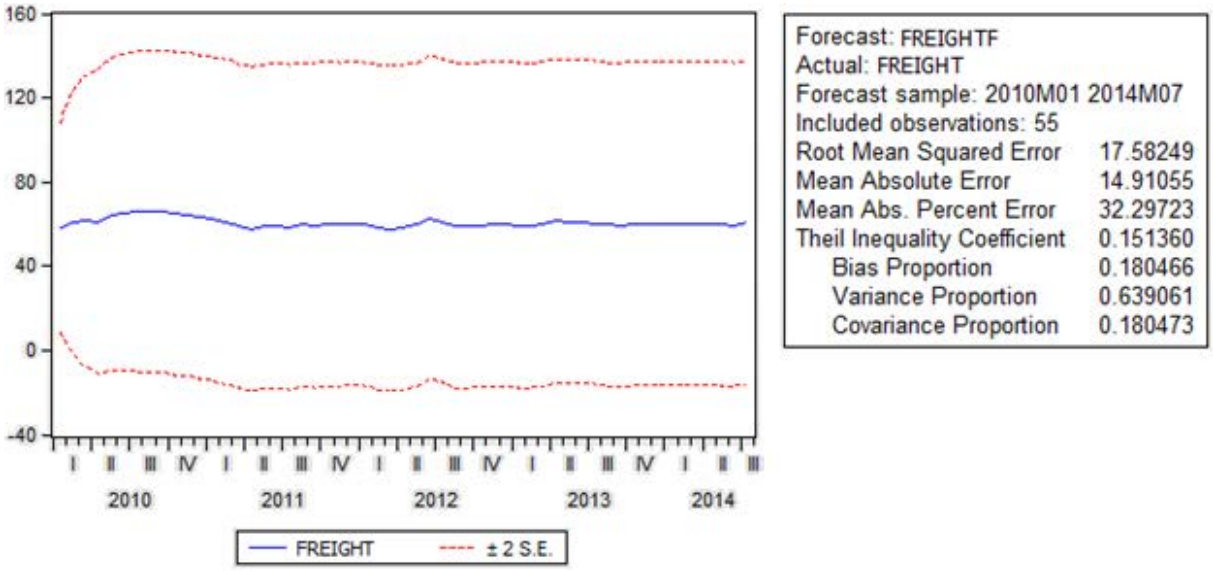
Two models were created and Durbin-Watson Statistics was used (First model has 0.47). For the second model Durbin-Watson Statistics was better – 2.



Graph 2.2. Model 2 data.

The final relation for the route Persian Gulf – Japan has the following form

$$FREIGHT = - 47{,}12 * \log(OIL) + 196{,}9 + [AR(1) = 0.76]$$

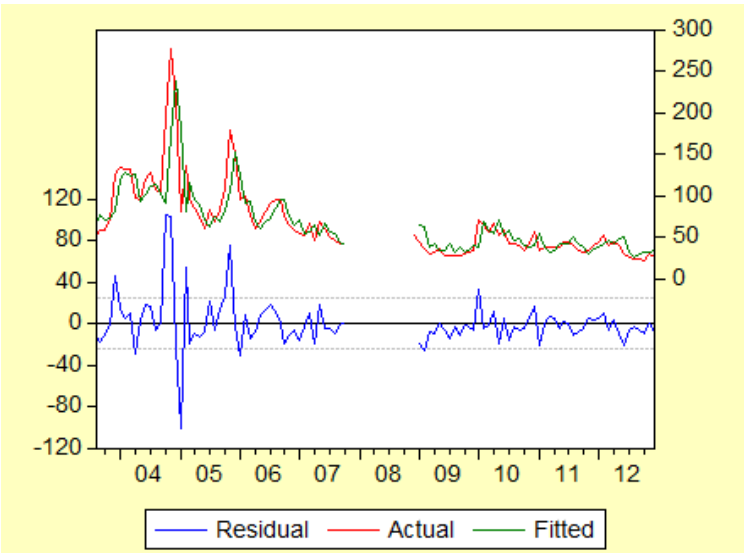


Graph 2.3. Retro-forecasting for Model 2, period 2010 – 2014.

Mean Absolute Error (MAE) was also determined for the above mentioned route – the result is 15. Mean Average Percentage Error (MAPE) was 32%.

The same procedure was applied for modeling of the route Persian Gulf – Europe. Also two models were elaborated and the following results were obtained for the period of 2003 – 2012.

Durbin – Watson Statistics for model 1 was 0.45 and for model 2 was 2.0.



Graph 2.4. Model 2 – Persian Gulf – Europe.

The final relation is the following: FREIGHT = -66*log(OIL) + 478+ [ar(1) = 0,75].

MAPE in this case was 20%.

3.CONCLUSIONS

Exploration of hydrocarbon resources in the Arctic is on the agenda of several countries. Nowadays the effective using of logistical technologies is limited because of different reasons like lack of infrastructure, quite reduced cargo volumes transported etc. Logistics, supply chain technologies will be developed in function of economic activity in the region, construction of ports, oil depots, warehouses, roads and railways. But preliminary studies including transportation issues have to be developed.

About ten different tanker routes for transportation of crude oil have been analyzed during the first stage of study. Here only two destinations are present. Both destinations have quite difficult routes (channels, straits) and these factors and several other factors have a significant influence over the transportation costs. Crude oil transportation via the North Sea Route also will face with a number of factors and many of them have to be used in models linking oil prices and tanker transportation costs.

Effectuated study demonstrates that links between oil prices and freight rates exist but using of regression models with small number of components doesn't offer quite precise results for forecasting. Consider the necessity to increase the using of variable components, to take into account a number of important factors.

It is possible to create quite precise models for each route but in this case the using of key factors for exact route is needed. Possible to affirm that the share of different factors for different routes will be different.

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