

# Proceedings of the 18th International Symposium on Logistics (*ISL 2013*)

## *Resilient Supply Chains in an Uncertain Environment*

**Vienna, Austria  
7–10<sup>th</sup> July 2013**



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## INTRODUCTION

We would like to welcome our friends and colleagues to the 18th annual International Symposium on Logistics (18th ISL). It is 20 years since the first Symposium on Logistics was held in Nottingham and it is now considered as the premier international event in the field of Logistics and Supply Chain Management. As in previous years many members of the ISL community look forward to meeting, sharing and exchanging their research ideas and results in both the formal and informal settings which the symposium provides.

The concept of alternating the symposium every year between Europe and the rest of the World is now well established. This year's event in Vienna, Austria continues this tradition, following the very successful and productive event held in Cape Town, South Africa last year.

The chosen theme of the 18th ISL is "*Resilient Supply Chains in an Uncertain Environment*". This theme reflects the changes taking place in recent years resulting in increased complexity in supply chains, due to, for example, the growth of outsourcing and offshoring and the movement of goods around the world. At the same time, macro-economic factors such as rising raw material and energy prices and the economic downturn have placed additional pressure on many supply chains. The combination of these factors means that, managers are faced with bringing resilience into their supply chains to address these issues of uncertainty and risk. These changes have big implications for logistics and supply chain planning, representing a dynamic and interesting area of research and practice for both academics and practitioners alike. With this in mind, the 18th ISL has assembled experts from around the globe to focus on how leading firms and academics are responding to these challenges and debate what this will mean for the future of global supply chain management. Papers in the proceedings represent the latest in academic thinking, as well as case examples of successful practices and innovative approaches to counter act the current uncertain environment.

Potential authors were invited to submit an abstract to the Symposium Chairmen. All abstracts were reviewed by two experts from the International Advisory Committee and final papers were further reviewed by an International Panel of Reviewers. This book of proceedings of the accepted papers has been organised according the following categories:

- *Manufacturing supply chains*
- *Resilience in supply chains*
- *Risk and disruptions in supply chains*
- *Supply chain performance and assessment*
- *Inventory and warehouse management*
- *Maritime logistics*
- *Transport, distribution and 3/4PLs*
- *Retail logistics*
- *Humanitarian logistics*
- *Services and the supply chain*
- *Applications of ICT in supply chains*
- *Sustainability in logistics and supply chains*
- *Supply chain capability development*

We would like to take this opportunity to express our sincere thanks to all the presenters, delegates, reviewers, Advisory Committee members, and guest speakers for their constructive and valued contributions. Finally, our very special thanks go to Alison Parrett for her wonderful all round administrative support throughout the entire organization, often under stressful, demanding and unpredictable circumstances.

Professor Kulwant S Pawar and Dr Helen Rogers – July 2013

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#### **ABSTRACT**

Through a comprehensive desktop research reviewing the relevant literature and analysing secondary data, this paper evaluates the supply chain collaboration competency of the indigenous Chinese manufacturing firms from five key aspects: aligned strategies, collaborative planning and forecasting, information sharing, integrated and optimized logistics process, and collaborative training. It also identifies four major institutional barriers encountered by the manufacturers, including transactional relationship, poor inter-organizational information system, low performance of third-party logistics service providers (3PLs) and *guanxi*. The findings reveal that an increasing number of manufacturing firms have started to recognize that supply chain collaboration can be an effective tool to improve efficiency. Nevertheless, adoption of supply chain collaboration practices in China is not widespread and is limited to leading enterprises and regions only. Few Chinese companies have set up formal forecasting, demand management, or market intelligence unit for capacity and inventory planning. Their suppliers are often reluctant to provide detailed information about their operations. Furthermore, to improve the supply chain collaboration capability of the Chinese manufacturing firms, multiple institutional barriers will also need to be overcome.

#### **INTRODUCTION**

In 2010, multiple suicides and large-scale strikes by workers working in foreign companies in China such as Foxconn and Honda resulted in an average wage increase of 25 per cent a year in more than 20 regions (Berthelsen, 2010). There has been a general consensus that the occurrence of suicide incidents in Foxconn symbolizes the end of the cheap labour era of China. In contrast to what happened a decade ago when foreign companies flocked into China to benefit from lower manufacturing cost, multinational corporations have started to shift part of their production capacities from the traditional coastal regions in China to other destinations because of the wage inflation. Many foreign firms even adopt a "China+1" strategy by building an extra production base in another lower-cost Asian country (Zhu, 2012).

Along with the sharp ascending labour cost, other major challenges, such as surging raw material price, strong appreciation of the Chinese currency and an urge for sustainable business, have left little room for the indigenous Chinese manufacturing firms to make adequate profit. Those manufacturing firms, if continued to merely focus on production or manufacturing and stayed at the bottom location on Stan Shih's "smile curve" with the lowest value, can no longer provide profitable return or maintain competitiveness (Shih, 2005, p. 213-215). Climbing up from the bottom of the "smile curve" and participating in a wide range of supply chain management initiatives to add value to the products seems to be a viable alternative for the Chinese manufacturing firms to maintain its competitive position in the global market.

Disproportionally huge logistics cost in China indicates that the development of supply chain collaboration capability of its manufacturing industry is critical. However, the distinct Chinese institutional environment proves to be a hindrance to major efficiency improvement. Wide application of supply chain collaboration initiatives across the entire supply chain and prompt removal of major institutional obstacles appear to be the most promising solution.



Although the indigenous Chinese manufacturers have impressed the world for their prominent competency in production, their supply chain collaboration capability is one big area that has not been leveraged to achieve sustainable competitive advantage for the whole industry. Supply chain management is a relatively new concept for the manufacturers in China (Chen & Yang, 2003). An increasing number of manufacturing firms have started to adopt supply chain management practices as an effective path to cost reduction and efficiency improvement.

Manufacturing sectors world-wide are moving towards unprecedented level of supply chain collaboration. The current institutional environment is hampering attempt to substantially improve supply chain efficiency. It is therefore urgent for the Chinese manufacturing firms to embark on supply chain collaboration through adoption of modern managerial practices and removal of institutional barriers.

The purpose of this research is to explore the key elements of supply chain collaboration of the indigenous Chinese manufacturing firms and investigate the institutional obstacles inhibiting the wide adoption of supply chain collaboration in China. Based on a comprehensive desktop research reviewing relevant literature and analysing secondary data, a tentative framework for supply chain collaboration in the Chinese context has been proposed.

This paper is structured as follows: First, a literature review is conducted on supply chain collaboration and its benefits for the Chinese manufacturing firms. Then, the methodology of the study, which is primarily a desktop research with secondary data, is elaborated. After that, the findings of the analysis are presented. Finally, limitation of the study is discussed and directions for further research are also suggested.

## **LITERATURE REVIEW**

Supply chain collaboration is pursued by businesses increasingly as the key driving force of effective supply chain management (SCM) (Horvath, 2001) and the ultimate core capability to survive the inexorable competition (Sanders & Premus, 2005). Collaboration is described as an inter-organizational process where participants work collectively to make investment, share information (Simatupang & Sridharan, 2002), resources, awards and responsibilities, as well as to make decision and solve problem jointly to achieve common goals (Stank et al., 2001; Soosay et al., 2008). Similarly, Togar and Sridharan (2002, p. 19) defines supply chain collaboration as "two or more chain members working together to create a competitive advantage through sharing information, making joint decisions, and sharing benefits which result from greater profitability of satisfying end customer needs than acting alone".

Extant literature shows that there are many factors associated with the pursuit of supply chain collaboration. The basic motivation for collaboration among chain members is to exploit profit-making opportunities which cannot be realized alone while customers have become more demanding and competition is intensified (Hoyt & Huq, 2000). Whipple and Frankel (2000) propose that strategic collaboration facilitate buyers and suppliers to combine their individual strengths and work cooperatively to eliminate non value-adding activities and enable better performance. Ireland and Bruce (2000) believe that inventory accumulation is actually the driver of collaboration. It is because collaboration is an effective way to curb the "bullwhip" effect of overstocking and become more responsive to the turbulent market (Holweg et al., 2005). Furthermore, other incentives such as cost reduction, greater technological capability, shorter product life-cycles, ability to deal with uncertainty, and quicker new product development (Hoyt & Huq, 2000; McIvor & McHugh, 2000), are also some of the key impetus for supply chain collaboration.

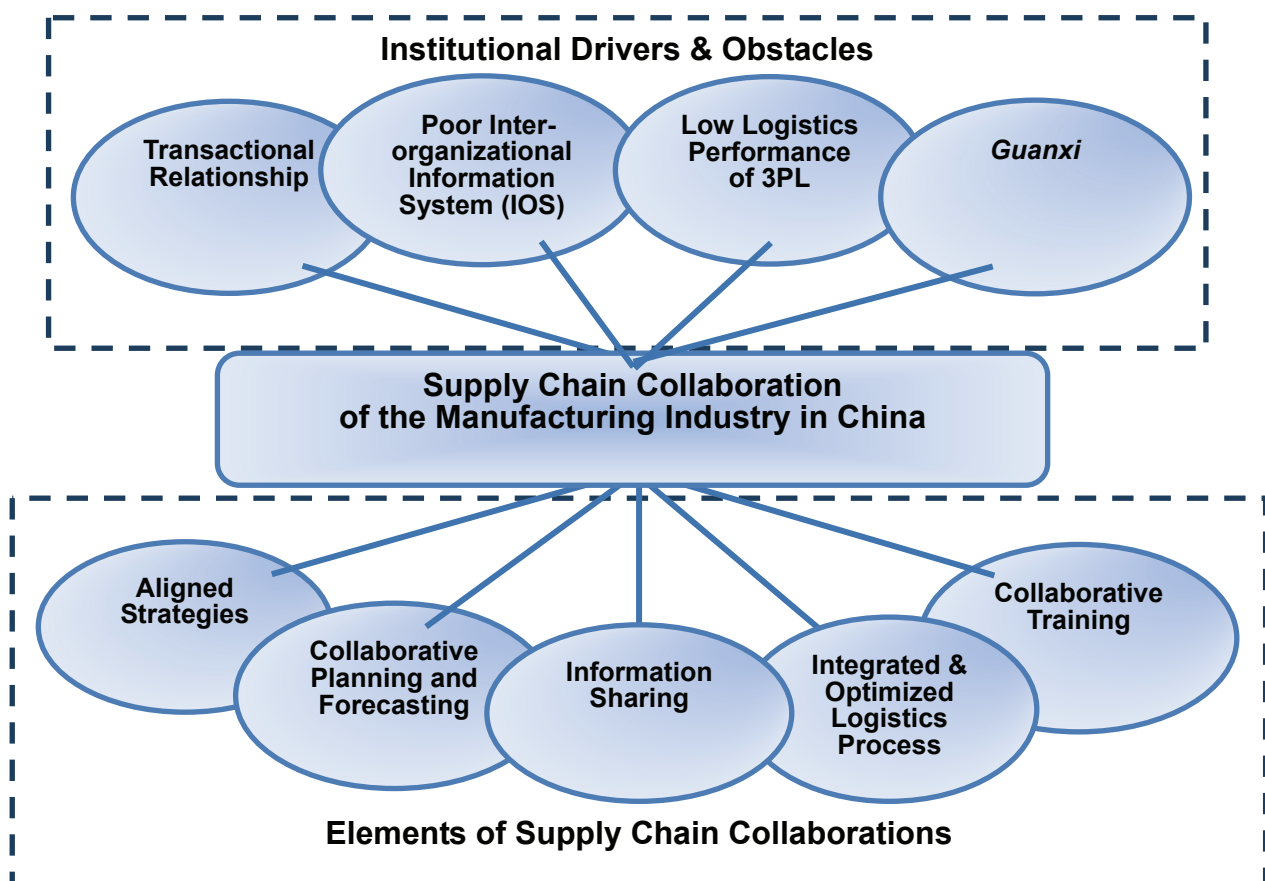
The prevalence of collaboration mainly roots in awarding tremendous benefits to organizations if it is successfully applied. Min et al. (2005) address that collaboration makes contribution to improvement of efficiency, effectiveness, and market positions for corporations. As Bowersox (1990) reports, strategic logistics alliances among partners and even competitors lead to better customer satisfaction, lower distribution and storage cost. After analysing several pilot programs, Fliedner (2003) highlights the benefits of collaboration in terms of increased sales, lower product inventories, obsolescence, deterioration for retailer, higher order fill rates, faster cycle times and reduced capacity requirements for manufacturer, as well as shared benefits such as improved forecast

accuracy and lower system expense. Overall, collaboration is an effective supply chain management tool enabling the attainment of various benefits for the chain members to achieve cost reduction, quality enhancement, operation accelerating through streamlining cross-organizational processes (Simatupang & Sridharan, 2005a).

Supply chain collaboration is, of course, not unproblematic (Barratt, 2004). Many barriers, such as lack of collaborative and strategic planning, difficulties in real-time information exchange, requirement of substantial investment, no shared target, lack of trust and unequal distribution of risks and rewards (Barratt & Oliveira, 2001; Chan et al., 2004; Fliedner, 2003; Ramesh, Banwet & Shankar, 2010), and practical difficulties in actual implementation (Johnston et al., 2004), have been noted. Nevertheless, there is a trend toward greater collaboration. Matopoulos et al., (2007, p. 177) argue that “despite the barriers that potentially deteriorate collaboration among companies for many industries all over the world, collaboration is becoming more of a necessity than an option”. Barratt (2004) observes that failure of supply chain collaboration is caused by a lack of understanding of what collaboration really means. Consequently, important enablers such as developing front-end agreement (Barratt, 2004), top management involvement (Sandberg, 2007), mutual trust (Ha et al., 2011), and information technology and sharing (Mason-Jones & Towill, 1997; Lummus & Vokurka, 1999) are crucial for successful collaboration.

With an overview of the key facets of supply chain collaboration in China and an understanding of the importance of an extensive collaboration among the various parties in the supply chain to benefit the Chinese manufacturing firms, a tentative conceptual framework for supply chain collaboration based on the work of Simatupang and Sridharan (2005) and customized for the unique economic, political and cultural situation in China has been proposed (see Figure 1). At this stage, the framework only shows the key elements of supply chain collaboration involved and the institutional obstacles identified in the literature. Detailed relationships among these elements and obstacles have yet to be determined. Upon investigation of the key elements of supply chain collaboration and the views of the practitioners, it is hoped that the proposed framework can be refined by revising some of the elements and barriers or incorporating new ones that have not been identified in the literature.

Figure 1: A proposed framework for supply chain collaboration of the manufacturing industry in China



## **METHODOLOGY**

This study uses a desktop research to review the literature comprehensively to identify the key elements of supply chain collaboration of the Chinese manufacturing firms and the multiple institutional barriers they encountered. Desktop research, which is similar to the case study method, is appropriate for preliminary exploration of a problem which is not yet clearly defined or fully understood. It is commonly regarded as an appropriate research technique when “how” or “why” questions are asked, the examiner has little control over the phenomenon, and concerned with a contemporary event in the real world (Yin, 2009). This approach offers the key opportunity to disentangle the complexity and recognize a phenomenon in depth and comprehensively (Easton, 2010).

To obtain a holistic picture of the supply chain collaboration of the Chinese manufacturing firms, published secondary data, such as journal papers, and consultancy papers from IBM Global Service and an economist intelligence unit sponsored by Cisco, were used for analysis. The key elements of supply chain collaboration of the Chinese manufacturing firms and the institutional barriers they are facing were also investigated.

## **FINDINGS AND DISCUSSION**

### **1. Key Elements of Supply Chain Collaboration**

Since China’s adoption of economy reform and open-door policy, Chinese manufacturers have convinced the world for their prominent competency in production. However, their supply chain management capability is relatively weak in comparison to the Western firms (Pyke et al., 2000). There is a consensus that supply chain management skills of the Chinese manufacturing sector are still immature (Chen & Yang, 2003). However, it is also observed that the interest in SCM research in China has surged recently (Zhao et al., 2007). An increasing number of manufacturing firms have started to accept the idea that supply chain management can be an effective tool to improve efficiency. This will lead China to a brand new supply chain management phase although it takes time for knowledge to be diffused among lower-tier suppliers and across the entire country.

However, the global manufacturing sector has evolved from the initial supply chain management towards a focus on process innovation and unprecedented collaboration across the supply chain (Zhu, 2012). To succeed in the global marketplace, the Chinese manufacturers must engage in cross-border collaboration to keep abreast with their leading global peers without delay. Multiple obstacles to substantial improvement of supply chain capability and logistics efficiency of Chinese manufacturers do exist and many firms do not realize the importance of supply chain collaboration (Huang et al., 2012). Nevertheless, some Chinese manufacturers have demonstrated growing interest in supply chain collaboration with up and down stream partners. The level of adoption of supply chain collaboration practices by the Chinese manufacturers can be gauged from five key aspects, namely, aligned strategies, collaborative planning and forecasting, information sharing, integrated and optimized logistics process, and collaborative training.

#### *Aligned strategies*

Majority of Chinese manufacturing firms made less achievement than expectation from adoption of supply chain collaboration practices due to ignorance of appropriately aligned strategies at the beginning of implementation (IBM, 2006). However, the leading diversified white goods and electronics manufacturer, named Haier, realized the significance of aligned strategies such as adoption of effective performance metrics by linking performance of managers to the performance of other departments within their organization (Economist Intelligence Unit, 2009).

#### *Collaborative planning and forecasting*

Chinese manufacturers are adolescent at collaboratively demand forecasting and supply planning. Few Chinese companies have formal forecasting, demand management, or market intelligence unit for capacity and inventory planning (Handfield & McCormak, 2005). Huettner & Song (2007b) point out that only 17 per cent of the manufacturers surveyed in

their study deployed synchronization of supply and demand practices in China and wide application of this initiative is restricted by deficiency in the use of advanced technologies. Given that China is one of the most dynamic markets in the world, demand-forecast accuracy is hardly to be assured (Byrne, 2006). Since lack of training and education in supply chain operations, Chinese manufacturers have difficulty in coping with unsynchronized fluctuations from customers and suppliers, which can result in excess inventory or high rates of stock-out (Feuling, 2008; IT168, 2008).

#### *Information Sharing*

In China, manufacturers are often reluctant to provide detailed information about their operations (Carbone, 2004). Huettner & Song (2007b) estimate that only 12 per cent of local Chinese companies electronically share demand information and inventory data in real time with supply chain partners, compared to 50 per cent in India. China is short of accurate information and tracking system, which is largely caused by the lack of standardization in data collection and the sharing of information (MacDonald, 2004; Daly & Cui, 2003).

#### *Integrated and Optimized Logistics Process*

Many world-class best practices have not been well implemented or even recognized by most Chinese companies (Daly & Cui, 2003). Leading logistics management approaches and technologies such as value stream mapping, Six Sigma, lean production and radio frequency identification (RFID), barcode scanning, are not extensively implemented in China, although there is obvious improvement (Huettner & Song, 2007a; Daly & Cui, 2003).

#### *Collaborative training*

In order to deliver outstanding performance through supply chain collaboration, every supply chain member of the Chinese manufacturing industry needs to operate its own processes efficiently to produce excellent outcomes. In reality, majority of the Chinese manufacturers, especially their suppliers, do not possess the elementary knowledge of supply chain collaboration to enhance operation efficiency (Feuling, 2008). The only viable way to close the gap and improve capability is to seek assistance from supply chain members who possess the required expertise and experience through collaborative training.

In sum, compounded with insufficient implementation of information and communication technologies such as Electronic Data Interchange (EDI), Enterprise Resource Planning (ERP) system and Collaborative Planning, Forecasting and Replenishment (CPFR) model, supply chain collaboration practices in China are not diffused broadly and only confined to limited leading enterprises and regions.

## **2. Institutional Barriers**

Obviously, the issue of enhancing supply chain management efficiencies in China cannot be resolved by simply borrowing supply chain collaboration ideas that stem from successful Western market economies. The unique and extreme complicated institutional environment in China needs to be fully considered before applying any of the Western managerial initiatives. From the literature, four institutional drivers and obstacles including transactional relationship, inter-organizational information system (IOS), low performance of 3PL, and *guanxi* were identified as four critical issues that have to be factored into the equation.

#### *Transactional Relationship*

The Chinese manufacturers are not sophisticated in customer relationship management. It can be reflected by poor communication between sales groups and their end customers and low customer satisfaction rate. Customer relationship management (CRM) practices such as customer focus groups and automated cross-selling are not widely implemented in China to enhance customer satisfaction (Huettner & Song, 2007a). Chinese manufacturers are also incompetent in tracking and controlling key customer order management (COM) performance metrics. As a result, overall customer satisfaction remains at a low level.

The connection between Chinese manufacturers and suppliers remains at transactional relationship stage (Handfield & McCormak, 2005). Liu et al. (2008) contend that most of the manufactures do not have supplier evaluation system and have no ability to identify valuable suppliers as long-term partners. Low price is the only criteria for supplier selection

in China. Only very few firms realized the importance of building up strategic collaborative relationship with suppliers. However, long-term close cooperation between or among SMEs has emerged as a trend (Wang & Shi, 2007). Some Chinese manufacturers start to provide financial and technology support to enhance supplier's capability on aspects of quality control, production procedure and assembly line improvement.

#### *IOS*

Overall acceptance of new information and communication technologies by the Chinese manufacturing corporations remains quite low. Only a few major companies such as Lenovo, Haier and Huawei embarked on implementation of supply chain management systems including ERP and JIT for their business processes in 2004 (IT168, 2008). Feuling (2008) points out that many Chinese companies still track activities such as raw material order placement and production scheduling by hand or transfer data over the phone. Higher utilization of logistics technologies need to be enforced for purposes such as maximizing data visibility, making global business decisions quickly and correctly, tracking demand in real time, and enhance flexibility and responsiveness (Byrne, 2006b). However, the astute application of advanced technologies is also hampered by the reality that very few personnel exist in any part of the country with the requisite training and knowledge to implement ERP, JIT, TQM or other sophisticated logistics systems (Daly & Cui, 2003).

#### *Low Performance of 3PL*

Logistics outsourcing practices in Chinese manufacturing sector are not as popular as in western countries (Huettnner & Song, 2007a). The outsourcing is usually limited to traditional transportation, warehousing and customs breakage (Lau & Zhang, 2006; Hong et al., 2006). Byrne (2006) states that Chinese manufacturing corporations gradually start to use qualified 3PLs to fulfil distribution tasks while dedicating internal resources to strategic objectives and focusing on core capabilities. Hong et al. (2004) reveal that there are emerging logistics outsourcing functions such as logistics information system management and logistics system design.

#### *Guanxi*

*Guanxi*, as complementary and parallel mechanisms for directing economic interaction, plays decisive roles on business success or failure in Chinese society. As an unspoken rule, a company operating in China has to allocate resources to build up collaborative *guanxi* network with government and other business partners although such move incurs extra sunk cost (Schramm & Taube, 2003). By doing so, the company can benefit from preferential treatments, insider information, reduced interventions and lower transaction cost. Different from the Westerners, the Chinese usually only share information with someone they have close relationship with (Wank, 2005). Chinese corporations tend to choose suppliers and collaboration partners by evaluating closeness of *guanxi* between them. *Guanxi* is the prerequisite for entering into any form of collaborative activities with other businesses in China therefore affects the formation of supply chain collaboration among manufacturing firms.

The above reveals that it will be a hard road for the Chinese manufacturing firms to reap the fruit of supply chain collaboration successfully owing to the presence of various institutional barriers. It is critical for them to seek feasible solutions to overcome all those obstacles while building up seamless collaboration with their supply chain partners.

### **CONCLUSIONS AND FURTHER RESEARCH**

Through a comprehensive desktop research with analysis of secondary data, this study has investigated the key elements of supply chain collaboration among the indigenous Chinese manufacturing firms. It has also explored four institutional barriers encountered by the manufacturers. The findings indicate that the Chinese manufacturers are adolescent at supply chain collaboration although they are paying increasing attention to it. Various institutional barriers have to be surmounted to realize the immense advantage brought by synchronized supply chain collaboration.

This study is a preliminary research to examine the key elements of supply chain collaboration of the indigenous Chinese manufacturing firms and the institutional barriers faced by them. Although it does have contributed to knowledge by providing a snapshot of

the current situation, the use of secondary data has prohibited the gathering of more in-depth information to explore how each element should be enhanced to improve supply chain collaboration competency of the Chinese manufacturing firms and how the various elements of supply chain collaboration relate to each other. Although four institutional barriers have been discussed, a systematic approach to generating feasible solutions to overcome these difficulties has yet to be developed. Future research may adopt questionnaire survey or in-depth case study to collect comprehensive and concrete data for analysis. As such, all the key elements of supply chain collaboration in the Chinese context and the inter-relationships between the elements can be explored. Other crucial institutional barriers can also be identified to facilitate formulation of appropriate strategies and policies to promote supply chain collaboration across the manufacturing sector.

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# **THE EFFECT OF USING MANUFACTURING LEAN TOOLS ON THE PERFORMANCE OF EMERGENCY DEPARTMENTS AT HOSPITALS; A Study in a Saudi Hospital**

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## **ABSTRACT:**

The emergency department (ED) is a vital part of any hospital; its structure should be constantly optimized in order to improve its performance to enable it to face the flow of the needy patients round the clock. Past Lean implementations have proved to be successful in hospitals and other healthcare settings in the United States, the United Kingdom, Canada, and Australia but no similar study were conducted in the Middle-East. This study examines the implementation of Lean principles in the ED of a Saudi hospital.

An interventional action research is conducted in order to identify the impact of Lean implementation on the patients' turn-around time (TAT) in a key area of the ED and to identify the impact of this intervention on the levels of staff satisfaction and staff knowledge of their workplace. The study has been conducted over a six month period, during which changes were introduced, surveys conducted and data collected. ED physicians and nurses were surveyed to evaluate the impact of lean improvements on their daily work. This data was supplemented with a measured sample of the TAT spent by the patients at the ED.

Lean tools implementation resulted in improvement of the satisfaction level of the ED staff about their workplace. Also the degree of their perception that the daily tasks are being executed in a smoother manner than pre-Lean implementation has improved. The overall average score, using a Likert-scale of 1 to 5, of the questionnaire distributed to the selected ED staff increased from 2.9 before, to 3.5 after implementation. The average turnaround time spent by the ED patients decreased from 70.3 minutes before, to 66.3 minutes after Lean implementation. This difference was found not to be statistically significant using a paired sample *t*-test which requires further investigation. On the other hand, the staff responses to two thirds of the questionnaire questions showed statistically significant improvement using a paired sample *t*-test.

The results of this study can be used by other EDs to develop approaches for improving the efficiency of healthcare delivery to patients. Moreover, as long as there are many similarities between the ED structure and function and the structures and functions of other clinical areas in the hospital, it is recommended to extend the implementation of Lean tools to other clinical areas such as operations rooms, outpatient clinics and inpatient wards/units. The fact that this study was applied on the ED of a single Hospital would make it difficult to generalize its results. It is recommended to test the applicability in different hospitals and different areas.

**Keywords:** Lean, 5Ss, Spaghetti Diagram, healthcare, hospital emergency department.

## **Introduction**

Emergency departments (EDs) provide a vital public service; that is emergency care round the clock (Derlet et al., 2001). Overcrowding is the most serious issue which challenges EDs in the developed world (Fatovich, 2002). Prolonged waiting times at the ED may result in delay of providing the appropriate care and treatment to patients. Delays in diagnosis and treatment of time-sensitive cases have been attributed to ED crowding (Trzeciak and Rivers, 2003). Moreover, prolonged waiting times may lead to patient/escorts dissatisfaction, patients leave without being seen (LWBS) and ambulance diversions (Hoot and Aronsky, 2008; Derlet and Richards, 2000). Ambulance diversions can simply subject the general public to the risk of not receiving the appropriate care in a timely manner (Drummond AJ., 2002).

Lean management principles have been used effectively in manufacturing companies for decades, particularly in Japan. Nowadays, it is strongly believed that those principles can be successfully applied to the delivery of healthcare (Kim et al., 2006). Since healthcare organizations are nowadays facing increasing pressures from consumers, industry and governments to deliver their services in a more efficient and effective manner; hospitals and healthcare delivery systems started to hire management consultants to help them improve processes, techniques and tools. This study aims to identify the effect of using Lean principles and tools on the performance of the ED in an acute care Saudi hospital. This type of study has never been conducted in a hospital in the Middle East region.

## **2. Literature Review**

Studies have demonstrated successful applications of Lean thinking to health care process improvement activities. Virginia Mason Medical Center in Seattle (USA), Flinders in Australia and the Royal Bolton NHS Foundation Trust in the UK have become influential examples of Lean implementation in health care settings (Kelly et al., 2007; Fillingham, 2007; and Ben-Tovim et al., 2008). Flinders Medical Centre in Australia could achieve higher ED productivity using the same physical space, the same number of staff previously utilized and the same technology. Moreover, there was a diminished turnover of the ED staff and a sharp decrease in the number of patients LWBS (Ben-Tovim et al., 2008). The Royal Bolton Trust also reduced the pharmacy turnaround time (TAT) by 30% and the pathology TAT from over 24 hours to 2-3 hours resulting in using less space and less resources (Fillingham, 2007).

### **2.1. Approaches to Lean Implementation**

In many of the studies, it was found that hospitals adopted the "systemic" approach to Lean (Hagg et al., 2007; Ben-Tovim et al., 2008; Dickson et al., 2009; Grove et al., 2010; Ng et al., 2010). These hospitals cited a cultural view of Lean implementation where staff at all levels are empowered and engaged in improving how things are done on a continuous basis; this would ensure a long-term sustainability of improvements. In other studies, hospitals considered lean as tools that help in improving performance (Avni, 2007; Kelly et al., 2007; Wojtys et al., 2009).

In some cases, external Lean consultants shared in the development and implementation of the Lean system; those consultants were either from standalone consultancy firms (Ng et al., 2010) or from university-affiliated academic institutions (Hagg et al., 2007). In other cases, assigned team members from the facility staff were sent to have the relevant training at an external educational facility to help them gain the required knowledge and skills (Ben-Tovim et al., 2008). Laursen et al. (2003) could not find a Lean Danish hospital at the time of their study or even one that was on its way to become lean. They decided to proceed with their study by themselves and conduct an "action" research in which a hospital is being converted into a Lean organization.

### **2.2. Outcomes of Lean Implementation**

Many tangible outcomes of Lean implementation in healthcare facilities have been achieved such as reduction of processing or waiting times (Fillingham, 2007; Hagg et al., 2007; Kelly et al., 2007; Ben-Tovim et al., 2008; Eller, 2009; Grove et al., 2010; Huggins, 2010; Ng et al., 2010), providing a safer care (Fillingham, 2007; Ben-Tovim et al., 2008; Newell et al., 2010), improved efficiency (Fillingham, 2007; Ben-Tovim et al., 2008; Grove et al., 2010; Kelly et al., 2007; Laursen et al., 2004; Newell et al., 2010; Ng et al., 2010; Wojtys et al., 2009), increased capacity without adding to the infrastructure (Laursen et al., 2003; Bahensky et al., 2005; Ben-Tovim et al., 2008) and reduction in costs (Bahensky et al., 2005; Huggins, 2010). Also intangible outcomes have been achieved such as increased employee motivation and satisfaction (Ben-Tovim et al., 2008; Wojtys et al., 2009; Newell et al., 2010), and increased patient satisfaction (Dickson et al., 2009; Wojtys et al., 2009; Newell et al., 2010; Ng et al., 2010).

### **2.3. Applicability at Different Healthcare Settings**

Lean Thinking was successfully implemented by many researchers in the ED such as Ben-Tovim et al. (2008), Dickson et al. (2009), Eller et al. (2009) and Ng et al. (2010).

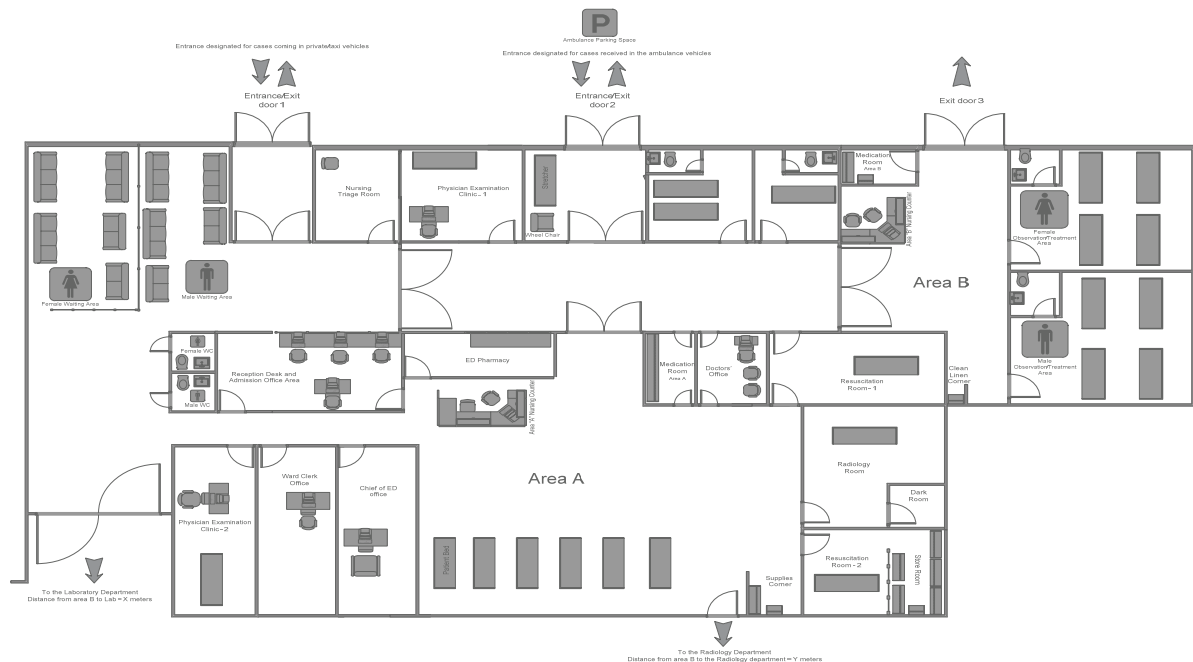


Moreover, many others such as Avni (2007), Wojtys et al. (2009) Grove et al. (2010), and Huggins et al. (2010) successfully examined the Lean techniques at outpatient clinics. Also others such as Fillingham (2007) and Newell et al. (2010) improved the workflow by implementing the Lean thinking in inpatient wards.

### 3. Study Outline

#### 3.1. Hospital Presentation

The hospital, in which the study was conducted, is a Joint Commission International (JCI)-accredited key healthcare provider in the western region of Saudi Arabia. It is managed by an autonomous organization under the Saudi government. The hospital is an acute care setting which provides both ambulatory services and inpatient services. This hospital was selected for conducting this study for convenience reasons. This hospital's ED is the major portal through which the served community accesses the hospital. The average annual volume that passes through the ED is about 90,000. The need for this study stems out from the large number of patients passing through the ED. Improving patient wait times and exploring new areas of opportunities are crucial for this hospital to continue providing excellent healthcare to its beneficiaries. In order to better understand the work environment inside the ED, a simplified floor map is provided in figure 1. This floor map was developed after two environmental rounds were conducted inside the ED area in order to be able to identify the distribution of the rooms/areas and the function of each room/area.



**Figure 1:** ED floor map showing the distribution of different area/rooms

The research question for this study is **“What is the effect of using Lean tools and techniques on the ED performance?”** The ED performance shall be monitored through some key performance indicators (KPIs). The first is the average TAT spent by the patients inside the ED. The second is the average scores of the ED Staff responses to the questions inquiring about their perception, satisfaction and knowledge of their workplace. Thus, the independent variable (IV) in this study is the Lean implementation and the dependent variables (DVs) are the TAT of area “A”, the location designated for receiving the critical or serious cases at the ED, the ED staff satisfaction, their positive perception of their workplace and their better knowledge about their workplace.

This study has one main hypothesis that investigates the effect of lean tools implementation on the improvement of ED in hospitals. This main hypothesis is broken down into 10 sub-hypotheses. The first 9 hypotheses are based on the 9 questions of the questionnaire distributed to the ED staff and the 10<sup>th</sup> hypothesis is based on the average TAT of the ED patients. The hypotheses are as follows:

The first 8 hypotheses start with "The Lean implementation in the ED improves the ED staff perception that": H<sub>1</sub>: their workplace is a well-organized; H<sub>2</sub>: they lose much time to search for the required items and retrieve them from their storage locations; H<sub>3</sub>: they lose much time to search for the required portable equipment and retrieve them from their storage locations; H<sub>4</sub>: they lose much time in the verbal communications while inquiring about the locations of the items during the patient care provision; H<sub>5</sub>: they make many trips inside the ED to accomplish the patient care-related tasks; H<sub>6</sub>: their workplace is an efficient one; H<sub>7</sub>: the current organization of the ED workplace may play a role in them making errors/mistakes during the care provision for the ED patients; H<sub>8</sub>: their workplace is user-friendly. Then the last 2 hypotheses are: H<sub>9</sub>: the Lean implementation in the ED improves the ED staff overall satisfaction level about their workplace; H<sub>10</sub>: the TAT of the ED patients improves with the Lean Implementation in the ED.

#### **4. Methodology**

An action research was used in this study. This involves the introduction of changes in the workplace of the ED of the hospital to identify the impact of those changes on performance. This work can be seen as a "*longitudinal interventional action research*" implemented at a single organization with quantitative data collection approaches.

##### **4.1. Population and Sampling Design**

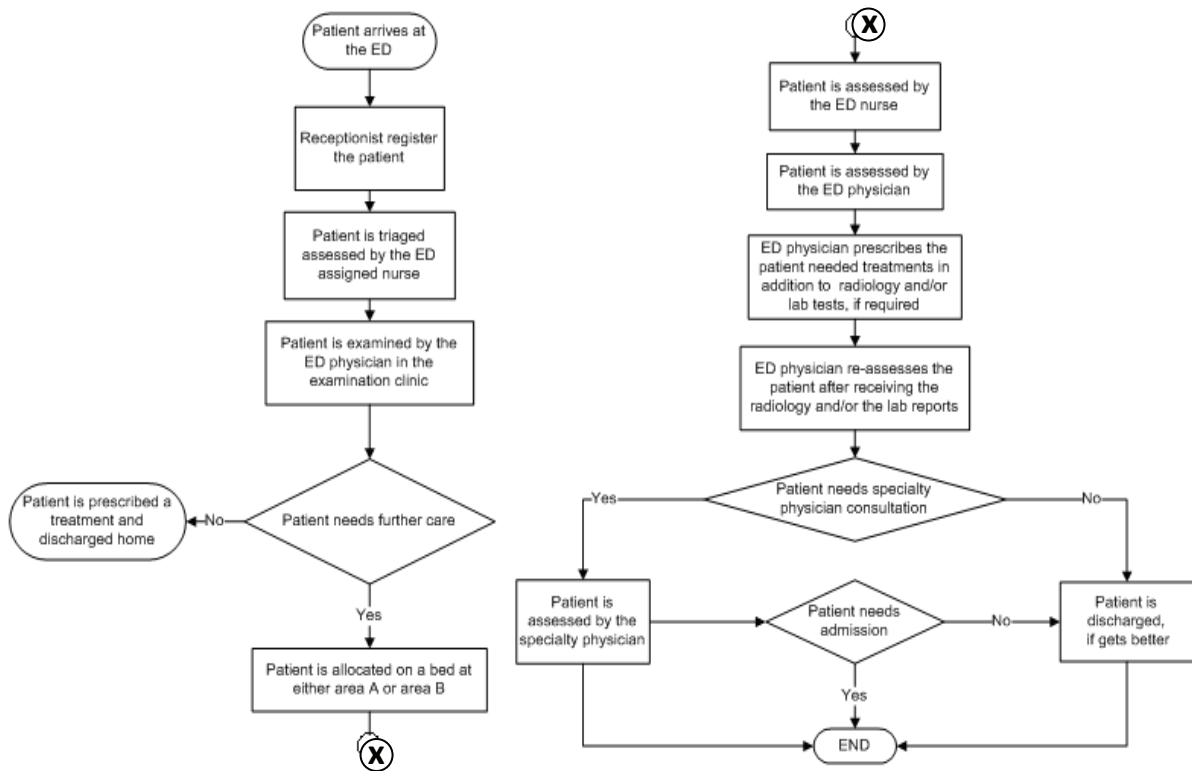
ED patients, who are only admitted to area "A" of the ED, are included in this study. The selected sample excluded the Obstetrics and Gynecology cases, who are fast-tracked in two designated rooms once they arrive and the psychiatric cases, who's attitudes/ behaviors are unpredictable and might affect their course of treatment and subsequently their length of stay inside the ED. Patients who are directly discharged home after being examined at the ED were also excluded from the sample. Data of the TAT of area "A" patients, which start with the patient registration at the ED reception and end with the patient discharge from the ED, were collected from the hospital's information system. A systematic random sampling technique was used to select the days which represent the 7 days of the week; the data of the ED patients who visited the ED during those 7 days were analyzed. For identifying the level of perception of the ED staff about their work environment, a questionnaire was developed and distributed to a selected group using the convenience sampling technique; the physicians and the nurses.

##### **4.2. The ED Structure and Workflow at the ED**

As shown in figure 1 above, the ED has a total of 22 beds. Those beds are distributed as follows: 8 beds in area "A" (2 of those 8 beds exist inside 2 separate resuscitation rooms and the remaining 6 are allocated in the main reception), and 8 beds in area "B", that is designated for receiving the less critical cases at the ED, (distributed equally among 2 separate rooms, one for males and the other for females). In addition, the ED has 1 triage clinic, where the triage nurse works and 2 examination clinics, in which the ED physician examines the patient to identify his/her severity category and subsequently allocate him/her in the appropriate clinical management stream. Moreover, the ED has a medications room, a store room and its own X-ray room. In order to better understand the process of patients' management at the ED, meetings and interviews were held with the ED staff and time was spent in the ED to observe the work flow. Based on the information gained from both the meetings and observations, a flowchart was developed as shown in figure 2.

##### **4.3. The ED Pre-Implementation Performance Measures**

Seven days were selected from the two months of September and October 2011 using systematic random sampling in order to analyze their data. Holiday periods were not included to avoid any special ED visitation pattern that differs from the routine visitation pattern. During the selected 7 days, a total of 491 patients were treated at areas "A" and "B". Of those, 196 cases received their treatment at area "A". TATs of area "A" cases were recorded and the average TAT was equal to 70.3 minutes as shown in table 1.



**Figure 2:** High-level Flowchart for the Patient flow inside the ED

**Table 1:** Number of cases treated at area A and the average TAT spent by them during their stay at the ED on the 7 randomly-selected days of September and October 2011.

	Average TAT Date	Number of cases seen at area "A" on each day	Average TAT $\bar{x}$ of area "A" patients (in minutes)
Saturday	17 September	37	80.5
Tuesday	20 September	37	69.4
Sunday	25 September	28	86.3
Friday	30 September	21	52.2
Wednesday	12 October	9	52.1
Monday	17 October	33	95.1
Thursday	27 October	31	56.3
		Total = 196	$\bar{x} = 70.3$

#### 4.4 Development of the Staff Survey Tool

A questionnaire was prepared by the researcher to use as the survey tool with the selected ED staff. This questionnaire is administered twice; before and after the lean implementation. The objective of this is to identify the change in the perception of the ED staff about their workplace after the "Lean Interventions". This is to explore the extent to which the

arrangement of the current workplace is helping the staff to accomplish their tasks in an efficient and smoother way. This questionnaire was distributed using convenience sampling to six Physicians (representing 50% of the current ED physicians) and twenty-two nurses (representing 59% of the current ED nurses). Five-point Likert-scale was used for the responses format. Two orientation sessions were given to the staff in order to raise their awareness about the Lean principles; one given to the ED nurses and the other given ED physicians. In order to ensure the validity of the developed questions, the researchers made sure that they are clear, specific, explanatory and sometimes provided with helpful examples. In order to ensure the reliability of the questionnaire, 4 of the questions included in the survey implied positive situations/ scenarios while the other 5 implied negative situations/ scenarios. During analysis, the positive questions response was assigned weights such that the "Strongly Agree" response had a weight of 5 and the "Strongly Disagree" response had a weight of 1. On the other hand, the negative questions response was assigned reversed weights. The logic behind this is to ensure the consistency of the data during the analysis.

#### 4.5. Questionnaire Analysis

Four of the returned twenty eight questionnaires were discarded after their responses were found to be inconsistent. The remaining twenty four questionnaires were analyzed. The analyzed data demonstrated an overall average score of the responses equal to 2.9 (this is equivalent to a "neutral" attitude after referring to the five-point Likert-scale average ranges as shown in table 2) and the mode was equal to 2 (which is equivalent to the "disagree" response).

**Table 2:** The different ranges of the average score calculated and the corresponding degree of agreement to each range (adapted from Abdel-Fatah and Aref, 2007)

Average Score Range	Corresponding Degree of Agreement
From 1 to 1.79	Strongly Disagree
From 1.80 to 2.59	Disagree
From 2.60 to 3.39	Neutral
From 3.40 to 4.19	Agree
From 4.20 to 5	Strongly Agree

In order to identify if there is any relationship between the duration of the respondents' work at the ED and the degree of their satisfaction and knowledge about their workplace, the coefficient of correlation between the average score of the responses and the duration of work at the ED (in months) were calculated. The value of the correlation coefficient was found to be 0.173, which almost shows no correlation between the two variables. Therefore, it could be concluded that the work duration of the ED staff does not affect the degree of their perception, satisfaction and knowledge of their workplace.

#### 4.6. Spaghetti diagram

Hard copies of the ED floor layout (figure 1) were printed and distributed to some of the ED nurses who serve in area "A" to sketch their motion patterns inside the ED. The involved nurses were instructed to record their trips during serving area "A" patients on map by drawing lines to represent their movements. One floor map was used for each patient case. Each nurse was asked to draw a line from one point to another whenever he/she moves between the two points. They were advised to ensure that the lines representing the same trips are parallel and not intersecting with each other. Intersections were only allowed when trips routes intersect.

After collecting the completed spaghetti diagrams and studying them, it was noted that, with 100% of the cases admitted into any of the 6 beds in the main reception of area "A", nurses visited both the medications room to get the required medications and the fluids, and the store room or the supplies corner to get the supplies needed for those patients. It was also noted that those trips were minimal when the patients are admitted into any of the 2 resuscitation rooms in area "A". This is explained by the fact that the resuscitation room is

usually well equipped and supplied with a wide range of items that might be needed for treating various clinical conditions.

## 5. Interventions

### 5.1. Lean Implementation

5Ss tool was used to organize the ED workplace in area "A" in order to make it more user-friendly and to save the ED staff time and effort which may be lost while searching for the needed items, equipment and/or trolleys. Several meetings were held with the ED staff (physicians and nurses) and multiple in-site rounds were made in area "A" of the ED in order to study the current practice for retrieving the needed items and to identify the applicable interventions that may be introduced. Many interventions were developed and implemented in collaboration with the ED physician and nurse who were assigned by the ED manager to assist in this study. Those interventions are listed in table 3.

### 5.2. Post-Implementation Data Collection

After lean implementation, the questionnaire was distributed to the same twenty four ED staff members that responded consistently to it prior to Lean implementation. They were instructed to respond according to their experiences in area "A" only where the Lean changes took place. The TAT data representing the seven days of the week, were selected randomly as was followed during the primary selection.

**Table 3:** 5Ss Lean interventions used in area "A", old practices and benefits gained are also listed

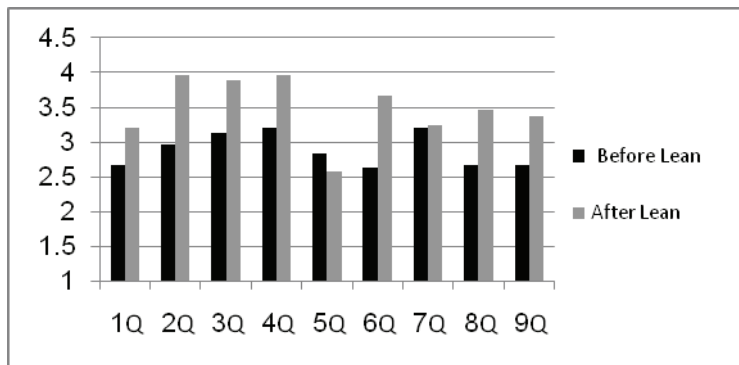
#	Old Practice	5Ss Lean Intervention
1	Only the 2 beds in the 2 resuscitation rooms had IV trolleys at the bedside.	Allocation of an IV trolley beside each of the 6 beds in area "A" so that all beds in area "A" have their own IV trolleys.
2	The items kept inside the drawer of the IV trolley were arranged in a cluttered and unorganized way that may cause the ED nurse to take a longer time searching for the needed item.	Organization of the items inside the IV trolley drawers was revised with the nurses and a new arrangement was used for those items to make the drawer visually helpful for any person that needs any item from it. This arrangement was standardized across all the IV trolley drawers.
3	The nurse had to call the operator to know the pager number of the specialty physician on-call.	A white board is posted at the back wall of the nursing station enlisting the pager numbers of all the specialty physicians on the daily on-call Rota which is updated every morning by the ED nurse in charge.
4	The physician or the nurse sometimes had to leave their work and escort area "A" patients to the ED pharmacy or the nearby radiology department.	Floor marking: a black tape was extended on the floor to guide patients and their relatives to the nearby Radiology department; another red tape was extended on the floor to guide the patients and their relatives to the ED pharmacy.
5	An ED patient may leave a bed in area "A" but still not all the ED staff are aware that the bed is now vacant, since in most instances this bed is hidden by a curtain. Sometimes, the physician/ nurse has to ask his/her colleagues about the status of this bed or he/she has to go to check the status of the bed.	A white magnetic board was posted on the wall at the nursing station; the ED staff was supplied with board markers, color-coded magnets and stick note pads. The beds in area "A" were enlisted in one column on the white board. The markers and color-coded magnets were used to identify the status of each bed in the next column and a third column was left for sticking notes about the case allocated in each bed, if needed.

6	The movable trolleys, located in area "A", like the electrocardiogram (ECG) machine trolley, the dressing trolley, and the plaster trolley did not have a specific location to be stored at after using them. Additionally, if any of those trolleys was taken away by one nurse to be used with one patient and another nurse needed it, she would search for it till she found it or she would postpone the patient care till the needed trolley was back.	Foot printing was done for the three trolleys: a tape was placed around place of the trolley. After identifying the borders of the area, an initial for the name of the trolley was taped on the floor inside this area such that "E" stands for ECG, "D" stands for dressing, and "P" stands for plaster. Also, a pad of stick notes was posted on the wall just above the trolley so that if a nurse takes this trolley, she writes on the wall-mounted notes the bed to which she is taking this trolley. This stick note should be discarded once the trolley is returned back to its storage area.
7	The supplies stored on the shelves of the cabinets at the store room and at the supplies corner in area "A" were not arranged in a certain systematic or logical way. So whenever any ED nurse needs to get any items from those shelves, he/she would need a long time to reach the item/s needed.	The arrangement of items on the shelves of the cabinets located at both areas was revised. After consulting a physician and a nurse, those items were organized such that rapid-moving items are kept in the cabinets located in the supplies corner which is nearer to the patient care areas than the store room. Additionally, it was agreed that the shelves' frames shall be color-coded and organized according to the body systems. Moreover, a sample of the item contained in each box was attached to the outside of the box so that the content of the box is clearly identified.
8	Nurse may make multiple trips to the medication room to get the IV fluids which may be needed for the patient. In most instances, the patient may receive one or more of the fluids during his/her stay.	Four of the most frequently used IV fluids (whether by type or by concentration) were put on the IV stand at the bedside of each of the 6 non-resuscitation beds in area "A". The other two resuscitation beds have them already.
9	Opaque cabinet/trolley drawers and doors only had labels on the outside to indicate the items(s) kept inside.	Images displaying the content of the drawer / cabinet were attached to the opaque drawers and doors.

## 6. Results AND Discussion

The average TAT of 199 ED patients, who attended at area "A" on the seven randomly-selected days during April 2012 was found to be 66.3. that is 4 minutes less than the pre-implementation value (i.e., 5.7% reduction). To test the significance of the difference between the pre-and-post implementation values, a paired-sample t-test was performed at CI of 95%. It was found that the significance level (p-value) is 0.439 which is much greater than 0.05 demonstrating statistical insignificance. Accordingly, one fails to reject the null hypothesis that the TAT of the patients is not affected by Lean implementation.

The post-implementation survey results demonstrated improvement in the satisfaction level of the ED staff about their workplace in area "A". Moreover, the survey proved that area "A" had become a more efficient, organized and user-friendly work environment. With reference to the five-point Likert scale ranges, the analyzed data gave an overall average score of the responses was 3.5, which is equivalent to a "agree" response and the mode was equal to 3, which is equivalent to "neutral" response. The pre-Lean implementation value of the average satisfaction score was 2.9 and the mode was 2.



**Figure 3:** Differences between the means of the responses for the 9 questionnaire questions, before and after Lean implementation.

For each individual question, the strongly agree/agree responses were combined in one category and the strongly disagree/disagree responses in one category. It was found that 41.6% of the respondents are satisfied with the ED as a workplace (compared to 25% pre-implementation (pre-imp)), 46% of the respondents consider the ED workplace as being user-friendly (compared to 16.6% pre-imp), 41.6% consider the ED workplace as well-organized (compared to 21% pre-imp) and 62.5% think that the ED workplace environment as an efficient one (compared to 29% pre-imp). On the other hand, 8.3% of the respondents confirmed that they spend much time searching for the needed items (compared to 37.5% pre-imp) and 12.5% agreed that they spend much time searching for the portable equipment (compared to 37.5% pre-imp), only 4% agreed that they spend much time in verbal communications inquiring about the needed items' locations (compared to 29% pre-imp), 29% concurred that they make many trips inside the ED in order to accomplish the required tasks (compared to 46% pre-imp) and 12.5% supported the fact that the current organization of the ED workplace might indirectly contribute to the occurrence of any errors/mistakes during the care provision (compared to 25% pre-imp). Figure 3 demonstrates the scores of staff satisfaction before and after Lean.

A paired sample *t*-test was conducted at CI of 95%. The objective of this test is to identify if there is a statistical significance of the difference between the two means (before and after Lean) for each of the nine questions of the questionnaire. One can conclude that the pairs 2, 3, 4, 6, 8 and 9 have significance values (*p*-values) less than 0.05. Accordingly, one can reject their related null hypotheses and accept their related alternative hypotheses. On the other hand, it can be concluded that the pairs 1, 5 and 7 have significance values (*p*-values) higher than 0.05. Accordingly, one fails to reject their related null hypotheses.

Consequently, it could be concluded that Lean implementation in the ED causes improvements in many aspects such as the ED staff perception about the time lost while searching for the items needed, their perception about the time lost while searching for the portable equipment needed, their perception about the time lost in verbal communications with their colleagues inquiring about the location of the needed items, their perception that their workplace is an efficient one, their perception that their workplace is user-friendly, and the satisfaction level of the staff about their workplace. On the other hand, the average score of the responses to the question inquiring about the staff perception of their workplace as a well-organized one improved post-Lean but this improvement was found not to be statistically significant. Also, the average score of the responses to the question inquiring about the staff making many trips inside the ED during the patient care provision decreased post-lean and the average score of the responses to the question inquiring about their perception that the organization of the ED workplace would contribute to the occurrence of errors/mistakes slightly improved post-lean. The performed *t*-test for both questions showed statistical insignificance.

In this study, Lean techniques were used to improve the productivity and enhance satisfaction in the ED. One of the key findings of this study is that Lean manufacturing tools and techniques can be successfully implemented in healthcare settings like the ED of

hospitals; this is supported by the findings of many studies such as those by Hagg et al. (2007), Kelly et al. (2007), Ben-Tovim et al. (2008), Dickson et al. (2009), Eller et al. (2009), and Ng et al. (2010).

It was also found that there was an increase in the overall satisfaction level of the ED staff about their workplace after the introduction of the Lean interventions. This agrees with the findings of many studies such as those by Ben-Tovim et al. (2008), Wojtys et al. (2009) and Newell et al. (2010) which identified an increase in the satisfaction of the healthcare setting staff. The paired-Sample *t*-tests were performed on the data. The ED staff responses to the questions which inquire about their ability to reach for items/ equipment quickly has improved and this, in turn, reflected on the fact that the ED has become a more efficient workplace.

Using the 5Ss and the Spaghetti diagram Lean tools, many changes were introduced in area "A" of the ED to make it more organized, more user-friendly, with multiple guiding visual signals to ensure that the workflow inside this area is seamlessly smooth. In spite of all the interventions made, the average TAT of the ED patients was not significantly reduced which might reflect the fact that the duration of the patient's stay at the ED might be affected by other factors that contribute to the prolonged stay of the patient.

## 7. Conclusions

Lean manufacturing techniques could be applied within the ED of a Saudi hospital. Lean efforts focused on the area of the ED which usually receives the more critical or serious cases. By improving the workplace organization, providing visual aids, focusing on introducing methods that would minimize unnecessary verbal communication among the ED staff and arranging consumables in a manner that would minimize staff motion within the ED premises, staff satisfaction and knowledge of their workplace will improve. This could be achieved with minimal-cost and non-technological interventions. Lean thinking provides an approach to smoothing the work flow inside the ED and improving its efficiency by focusing on simple ideas that can be easily applied and customized, according to needs. The main limitation of this study that makes it difficult to generalize its results is the fact that it was conducted in the ED of a single hospital.

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# **SERVITIZATION OF CAPITAL GOOD MANUFACTURERS: AN EMPIRICAL RESEARCH IN ITALIAN MACHINERY SECTOR**

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## **1. INTRODUCTION**

Nowadays, services are increasingly taking the lead in global economy, in terms of both wealth produced and value added (Wölfl, 2005). This process involves also a radical shift in the way people and companies produce and use goods and thus it is affecting all the main industries, and especially manufacturing.

In manufacturing, services have been traditionally deemed as a necessary evil in the context of marketing strategies (Mathieu, 2001). Nevertheless, in recent years, services have been an important part of business of capital equipment manufacturers: an increasing number of manufacturing firms are trying to offer integrated solutions encompassing services and products. Especially in Engineer-To-Order (ETO) companies, there is an increased interest in adding value through the provision of services that extend the spectrum of their products and improve customers' satisfaction and loyalty.

The variability and uncertainty that characterized ETO firms (see for example Rahim et al., 2003), generate a complexity that requires specifically tailored managerial approach to handle all the processes: this is true also referring to service development and delivering processes. Also preliminary results of our study highlight that, although companies in this industry perceive the increasing importance of services for their business, they haven't still tackled the challenges of servitization: strategy and culture are still focused mainly on tangible product, service portfolio is underdeveloped and service delivery procedures not completely formalized.

This situation, along with the relevance of the machinery sector in the Italian economy, suggested us to better understand the state-of-art of "servitization" process and the perceived importance of Services in this industry.

Due to the exploratory intent of this study, we based our work on a multiple case studies empirical research (Sousa and Voss, 2001), aiming at answering the following research questions:

- How is perceived the Service Process in the Italian machinery sector?
- Are the Service Process structured and formalized inside companies? If, not what are the main reasons?
- How Service activities are supported by ICT?

The paper structure is therefore the following. In section two a brief analysis of the main features of ETO environment and servitization is carried out, in order to obtain a picture of the industry analysed in our empirical research. The objectives and the adopted methodology are depicted in section three, while section four describes the main findings based on case studies research. In the same section, the findings are discussed in order to point out the main messages of the work; conclusive remarks and directions for future research are drawn in section five.

## **2. CONTEXT**

The service component of Gross Domestic Product (GDP) in most OECD countries has reached 70% of total gross value added and about 50-70% of employment (Gao et al., 2009). Meanwhile, economic downturn has led to a demand stagnation on European markets. A direct effect is that, nowadays, Italian capital goods manufacturers export up to 70% of their production (Federmacchine, 2011). Moreover, due to globalization effects, competitive pressures generated by

manufacturers of low-wage country (e.g. China) have forced product margins to decrease (Gebauer et al., 2005). Evidences from Operations Management (OM) literature show that in such a context, extending the service business through what has been defined as a servitization (Vandermerwe and Rada, 1988), can lead to generate new, less imitable, competitive advantages and new additional revenues and profits (Wise and Baumgartner, 1999; Goffin and New, 2001; Oliva and Kallenberg, 2003; Brax, 2005, Neely, 2009; Baines et al., 2009).

According to Corti & Mills (2007), due to the characteristic of products, after sales service has always been an important part of business of capital equipment manufacturers. In fact, equipment life cycle can be very long (from ten to thirty years), the total cost of ownership for the end user is high and downtime is expensive. Moreover, items tend to be one-time purchases and since the purchase usually results from competitive bids, there is a downward pressure on prices for products that are frequently end-user customized. Furthermore, demand of capital equipment tend to be cyclical and this phenomena is emphasized by the growth of secondary markets (Zackariasson & Wilson, 2004). Even though all the above mentioned industry characteristics match the rationales that according to Wise & Baumgartner (1999) should lead manufacturers to extend their service business, only recently manufacturers have considered services from a strategic perspective: services can support not only the product but also customers and their processes. This new role has been made easier by the evolution of information technology solutions which enables companies to introduce new types of services such as the remote monitoring (Corti & Mills, 2007).

Starting from the importance of the servitization process in literature, we investigated the state of art of servitization of Italian capital equipment manufacturers that operate in ETO industries: ETO companies deliver products engineered (or optionally re-engineered) according to the specific requirements of a customer (Hameri 1997) and this leads to a more dynamic and uncertain environment (Hicks et al, 2001).

The main characteristics of the ETO paradigm could be summarized as follow: decoupling point located at design stage, complexity, high level of customization, low volume, long life-cycle, change in requirements and long lead times. As mentioned, one of the important characteristics is the level of customization (Stevenson et al. 2005; Gosling and Naim, 2009): the customer is crucial and company have to realize complex product that have to satisfy individual customers' specification (Hicks et al., 2007).

Adopting the ETO model, companies usually have to adapt managerial paradigms, business models and ICT supporting tools developed for other (i.e. the repetitive) sectors (Hicks et al., 2000). Especially from the ICT standpoint, the adaptation of existent tools leads too often to stand-alone applications and a low level of integration among different software, weakly supporting the business objectives.

Small size, high quality products, high innovation level, and export-orientation are the main characteristics of the Italian manufacturing companies and, in particular, of the machinery sector (UCIMU 2010). As a representative example of the relevance of this sector, Italy is the fourth producers of machine tools in the world (7.353 million euro, representing the 7,6% of the worldwide production), after China, Japan and Germany, and the third for exports (2.462 million of euro). Regarding more in detail the structural characteristics of this industry, the 68,4% of companies had a turnover less than 12,5 million € in 2009 and the 73,5% have less than 100 employees (UCIMU 2010).

In this ETO environment, companies have to guarantee availability of their complex machines and high productivity levels; as a matter of fact, a structured organization of service development and delivering processes along with an integrated ICT

support may become key factors to successfully deal with this context. Despite this, a preliminary (and more general) study (Adrodegari et al., 2012), carried out within 21 Italian special purpose companies (a specific instance of the ETO sector) show that service delivery processes are still focus on after-sales activities, with a poor dissemination of advanced services and some weaknesses concerning the ICT tools. Thus, we postulate that a formalized service process could represent a great opportunity for this kind of companies in order to increase revenues during the whole product life-cycle, reaching high profitability, picking-up information and feedback from customer and, last but not least, gaining competitive advantage against worldwide competitors.

For this reason, a more detailed analysis of Servitization process in ETO Italian machinery sector, along with supporting ICT tools, has been carried out and described in section 4.

### **3. OBJECTIVES & METHODOLOGY**

Given the context described in previous section, we postulate that a more structured approach to the servitization process, along with an efficient ICT support, may ease companies in optimizing service delivery processes and gaining competitive advantage in ETO environments. For these reasons, according to the research question defined in the introduction section, the main aims of this paper are the following:

- to investigate importance of the servitization process perceived by ETO companies that operate in the machinery sector;
- to analyse the organizational nature of the service strategic business unit;
- to analyse the nature of service portfolio;
- to highlight strengths and weaknesses of the service business processes evaluating their ICT requirements and support level.

The findings presented in the remainder of the paper (Section 4) are based on a *multiple case studies* empirical research, a form of quali-quantitative descriptive research that refers to the collection and presentation of detailed information about a group of companies, drawing conclusions about that group in a specific context. Case study research has been recognized as being particular good for examining the *how* and *why* questions (Yin, 2009). Due to the nature of the research questions and to the exploratory intent of the research, in order to achieve the objectives presented above, we carried out 9 case studies in companies operating in the ETO machinery sector. In fact, as reported by Voss et al. (2002) and Meredith (1998), case study allows the investigation of the phenomenon of interests in its natural setting (i.e. through the observation of actual practice). Thus, case studies allow for a richer knowledge of issues associated with the management choices than would have been possible through a quantitative approach (Nordin, 2005).

Meredith (1998) highlights some strengths of case research approach, which allows a relatively full understanding of the nature and complexity of phenomenon. Moreover, as pointed out by Voss et al. (2002), the case method lends itself to early, exploratory investigations where the variables are still unknown, such as in this study.

In our work, in order to select companies that owns observable traits that are key factors in our research questions, we adopted the judgmental sampling technique in which sample is based on the researchers' experience, knowledge of the sector and available data and includes ETO companies that as reach a certain peaks of excellence in various specific industries (from CNC machine centre to automatic assembly line design and manufacturing) and are heterogeneous in terms of dimension.

The selected companies are briefly described in Table 1.

Case Name	Turnover 2011 th EUR	Profit (loss) 2011 th EUR	Total assets 2011 th EUR	Employees 2011	Description
A	€ 66.176	€ 3.459	€ 54.646	222	Company A is the world leader in the production of printing machines designed for packaging applications
B	€ 39.492	-€ 341	€ 55.574	198	Company B is specialized in designing and manufacturing machining centers, flexible production systems and ad-hoc solutions for various applications
C	€ 6.019	€ 2	€ 6.875	42	Company C design, produce and commission industrial automation systems for the management of process automation of the iron and steel industry
D	€ 5.968	€ 26	€ 10.110	55	Company D designs and manufactures industrial machines (i.e multicenter and transfer)
E	€ 6.221	€ 3	€ 16.415	53	Company E studies, designs and builds machines and modules for the automation of assembly processes
F	€ 12.074	€ 494	€ 12.895	76	Company F designs, produces and assists solutions that help industries worldwide achieve consistent product quality
G	€ 5.377	€ 102	€ 6.076	40	Company G designs, produces and assists trimming machines
H	€ 5.979	€ 227	€ 5.494	29	Company H delivers a variety of solutions in the field of measuring instruments and testing benches
I	€ 28.595	€ 1.551	€ 26.940	79	Company I designs, manufactures, sells and supports plate bending rolls
<b>Average</b>	€ 19.544	€ 614	€ 21.670	88	

Table 1 – Company demographics (taken from Bureau van Dijk AIDA database).

A well-designed protocol is particularly important in multiple case research (McCutcheon and Meredith, 1993): also Yin (2009) recommended the use of a case-study protocol as part of a carefully designed research project. Following other studies in the ETO sector, our research protocol is summarized in “Figure 1”.

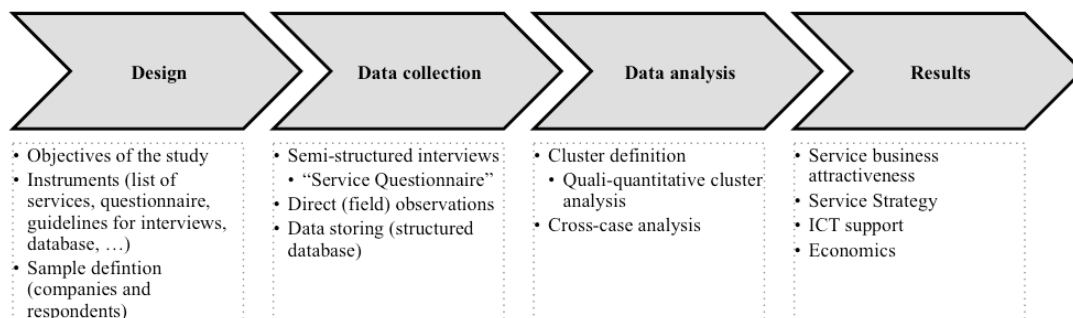


Figure 1 - Case-study protocol

Different instruments (data collection methods) were used, including semi-structured interview, direct (field) observations and a structured database in order to collect and store the information after each interview. During the semi-structured interview, to explore the research proposition, we used the “Service Questionnaire”, an MS Excel file that includes the topics to be covered during the interview, the questions to be asked and indicates the specific data required, that represented the core of the designed protocol.

The interviews, that were directed to specific key respondent within each companies (entrepreneur, CIO and Service Manager), started with broad and open-ended questions first, in which respondent were inquired about the Service organization and, as the interview progresses, the questions become more specific. In this phase, in order to better investigate the nature of service portfolio, we submit to respondents a detailed list of 41 services (divided in 14 categories), developed starting from literature (see in particular Oliva and Kallenberg 2003; Corti & Mills, 2007; Neely, 2009) and enriched with contribution derived from best practices.

According to the objectives of the study, the “Service Questionnaire” was organized in four main sections, as Table 2 shows:

Section (constructs)	Variables	References
<i>Service business attractiveness</i>	Respondent perception of services' contribution to the firm competitive advantage	Dimensions of service classification taken from Mathieu 2001; Oliva & Kallenberg 2003; Corti & Mills 2007; Gebauer et al. 2008; Neely 2009; Eggert et al. 2011
	Respondent perception of services' contribution to the firm profit	
<i>Service strategy</i>	Nature and clearness of Service SBU	Variables taken from Oliva & Kallenberg 2003; Oliva et al. 2012
	Number of service offered	
	Nature of service portfolio	Dimensions of service classification taken from Mathieu 2001; Oliva & Kallenberg 2003; Corti & Mills 2007; Gebauer et al. 2008; Neely 2009; Eggert et al. 2011
<i>ICT support</i>	Typologies of information systems (IS) adopted to support the activities of the Service SBU and service delivery processes	Variables elaborated from Agnihotri et al. 2002; Lehtonen and Ala-Risku 2005; Ala-Risku 2009; Brax and Jonsson 2009; Colen and Lambrecht 2013
	Respondent perception of the importance of IS to support service activities	
<i>Economics</i>	Installed base volumes	Variables taken from Wise & Baumgartner 1999; Oliva & Kallenberg 2003; Fang 2008; Neely 2009
	Ratio of installed units to annual new-unit sales	
	Percentage of turnover gained from services	
	Services marginality	

Table 2 – Constructs and variables investigated through the Questionnaire

Interview typically ranged from one to two days. In addition, some questions of the "Service Questionnaire" were discussed and elaborated upon. To argument the on-site interview and surveys, tours of the manufacturing facility were arranged: as suggested by (Voss et al., 2002), these plant tours provided an opportunity for verification and clarification interview responses.

The data collected through the interviews allowed to perform some cross-case analysis related to the investigated issues and are reported in the next section.

#### 4. MAIN FINDINGS AND DISCUSSION

The four dimensions pointed out in Table 2 were used to classify the case findings, hereafter summarized.

##### **Service business attractiveness**

By comparing service portfolio of studied companies with the perception of attractiveness of different typologies of service, has emerged that opportunities in terms of both achieve competitive advantage and increase profits, can be pursued by manufacturers extending the number of specific types of services offered. In particular, according to companies perception of the role of services in their markets and looking at their actual service portfolio, in order to improve their competitive position, ETO companies may develop and deliver more services aimed at support customers and their processes in the pre-sales phase (e.g. co-design services, analysis of customers processes, etc.) and in the after-sales phase (e.g. e-learning, suggestions on how to improve the equipment efficiency, etc.). Moreover, offering this kind of advanced services in the after-sales phase could also led ETO companies, again according to their perceptions, to gain higher profits. However, from interviews has emerged how, although advanced services (such as remote monitoring) have been developed years ago, customers don't perceived them as value adding and therefore are not willing to pay for them.

##### **Service strategy**

In order to investigate the existence of relationship among some of the variables related to the service strategy that are taken into account in the present study (see Table 2 for details), we clustered the sample on the basis of variables concerning

with the nature and clearness of service strategic business unit and according to theory measure orientation of manufacturers to service.

In particular, we attributed a grade to responses given by companies on each of the variables represented in Table 3. Thus, we ranked companies using the value obtained by summing up each score. From an organizational standpoint, according to theory, companies with an higher overall score (cluster one) present the most formalized service strategy among the studied companies, while companies with lowest score (cluster three) the less formalized.

Cluster	Case Name	Person in charge of services	The service function is	Service Strategic Business Unit (SBU)	Service SBU established	Service SBU nature	# of services formalized with procedures	KPI dashboard concerning Service SBU
1	B	Present	Formalized	Present	More than 10 years ago	Profit centre	All	Present
	A	Present	Formalized	Present	More than 5 years ago but less than 10	Profit centre	All	Present
2	I	Present	Formalized	Present	Less than 5 years ago	Cost centre	All	Present
	H	Present	Formalized	Present	Less than 5 years ago	Profit centre	All	Not present
	C	Present	Formalized	Present	Less than 5 years ago	Profit centre	Some	Not present
	F	Present	Formalized	Not completely formalized	More than 5 years ago but less than 10	Profit centre	Some	Not present
	D	Present	Formalized	Not completely formalized	Less than 5 years ago	Profit centre	None	Not present
3	E	Present	Not completely formalized	Not present	Not present	Not present	Some	Not present
	G	Present	Not Formalized	Not present	Not present	Not present	None	Not present

Table 3 – Organizational characteristics of the companies and cluster composition

As shown in Table 3, all case companies contemplate a person in charge of services delivery, however, only companies in cluster one and two have formalized an organizational function responsible for development and delivery of services. Going further in the analysis of the level of formalization of the service organization, companies that implement a formalized Strategic Business Unit (SBU) for the management of service size down to five. Moreover, the majority of these Service SBU have been established only recently, on average less then five years ago. In terms of accounting nature of the Service SBU, almost all the studied companies seems to have made one of the most important step of the servitization process, structuring it as a profit centre. Focusing on the service delivery, only four of the studied companies formalized all of their services using structured procedures. Finally, companies that implement a specific KPI's dashboard in order to monitor and control the performance of the Service SBU, that according to theory is another key issue in the servitization journey, are only three out of nine, and none of them consider the adopted dashboard fulfilling their needs.

Using the above explained clusters we further analysed the nature of service portfolio considering both the number and the typologies of services offered. In terms of number of services there seems to be no relationships with the level of formalization of the service organization. In fact, companies in cluster three offer on average the same number of services of companies in cluster two. However, looking at the different typologies of services offered, interesting differences among clusters emerge. In particular, companies in cluster one compared to other clusters offer a wider number of services aimed to support the customer and the product functioning both during the sales and the after-sales phase of the product life-cycle.

*Vice versa*, services supporting customer processes both in the pre-sales and in the after-sales phase are offered homogeneously by cluster one and three. From these results we drew the following conclusions, in the ETO machinery sector:

- high formalization of service organization is positively related with the offerings of services that aim to support the product functioning and the customer itself both during the sales and the after-sales phase of the product life-cycle;
- high formalization of service organization is not a prerequisite to offer services that aim to support customers processes in the pre-sales and after-sales phase of the product life-cycle.

Shifting the focus to the different typologies of service that can be offered emerges that some of them are not differential among cluster. That is the case of standard and consolidated services such as documentation, training, maintenance, spare parts, etc. While typologies of services that implies higher risks for the manufacturer that decide to provide them, such as the pay-per-use and warranty extensions, are more frequently offered by companies in cluster one. *Vice versa*, typologies of services that deal with co-design of the machines, financing, customers' processes optimization and asset remote monitoring are equally offered by companies of cluster one and three. Again, from these results we drew the following conclusions, in the ETO machinery sector:

- high formalization of service organization is positively related with the offerings of services which imply higher risks for the capital equipment manufacturers;
- high formalization of service organization is not a prerequisite to offer services strongly related with technological capabilities and capital equipment manufacturer's core competencies.

### **ICT support**

Results of present research confirm the perceived lack in the management of service processes: although in recent year the use of integrated information systems (IS) is grown, we observed a limited ICT support and a low level of satisfaction of companies. Studied companies consider ERP systems inappropriate to manage and support services and related information flows. In fact, the only company that has used it as main system decided to switch to a specific – though still ERP integrated - solution a couple of years ago.

Analysing in detail what IS companies implement to support each of their services, the ERP emerges as the widely adopted solution only for managing demand and provision of spare parts, services that are offered by companies from many years. *Vice versa* services such as machine installation and start-up, technical assistance (routine mechanical and electrical interventions), ticketing, training and machine efficiency advice are more often supported by ERP integrated specific IS such as CRM and PLM.

Although clear relationship between formalization level of the service organization and the adoption of advanced IS doesn't emerge from our analysis, companies with a higher formalization of service organization (cluster one and two) perceived the IS supporting service activities and processes as more important than companies without a formalized service organization.

These results led to the following conclusion, in the ETO machinery context: in order to manage and support service organization, service delivery processes and related flow of data/information, specialized and integrated solution such as CRM or PLM systems should be implemented.

However, from our case findings emerges that, as mentioned above, level of ICT support to service delivery in terms of typologies of IS used, change significantly over the service portfolio. For example, case studies show that after-sales services



are widely supported by IS than pre-sales services and during the sales services.

### **Economics**

Coherently with servitization theory, from case studies emerges that companies with a more formalized service organization manage a wider installed base. As done previously, we drew the following proposition, also in ETO machinery sector: wide installed base are related with high formalization of service organization.

Another evidence emerged from our analysis is that, installed base of companies with a more formalized service organization have grown slower than other companies in the last three years. This phenomena can be viewed both as a cause or as a consequence of the development of a service strategy. The former happens when due to demand stagnation or strong market competition, manufacturers decide to increase their investment in the development and provision of services. Conversely, the latter happens when, due to a specific input from the firm's decisional apex, a strong service strategy is put in place. In this case, the shift of investment from product to service could led to diminishing the product sold in favour of services.

### **5. CONCLUSION**

This paper is part of a larger research project, carried out in a ETO sector and focused on Servitization and Service Business Process. We adopted an explorative approach aimed to define the problem(s) and formulate proposition(s) that could be elaborated and tested in the next steps of the project. In particular, our study aims to build up the basis to extend the theory of servitization in a specific context such as the machinery sector. At the same time, on a more practical level, results of the present study shed a light on the servitization phenomena and we believe that further studies will help machinery manufacturer to take better decision when looking to extend their service business.

Summarizing findings described in the previous section:

- Through the analysis of services perceived importance, we identified which are the typologies of services that a manufacturer in the ETO machinery sector should provide in order to increase competitive advantage and profits. In particular, ETO companies are still offering traditional (support) services oriented to increasing product availability and reducing lifecycle costs, basing on condition-based maintenance and on spare parts management activities.
- Analysing the nature of service organization and service portfolio emerged that provision of some service typologies with specific characteristics such as services aimed to support the product functioning and the customer both during the sales and after-sales product life-cycle phase, seems to be positively related with the formalization level of service organization while others typologies are not.
- Analysing how service processes are supported through ICT systems emerged that advanced services aimed to support customers and their processes suffer a lack of support and that ERP systems do not well to support these kind of services.
- Finally, analysing firms economics, emerged potential linkages between variables such as the installed base dimension and service strategy. Specific area of future research has been identified:
- How IS support different typologies of services, in order to establish evaluation criteria that help manufacturers in the decision of implementation of specific IS aimed at ease management of services.
- Investigation of casual relation between variables such as the installed base dimension and service organization formalization level.
- Further research should also aim to clarify the direction and the intensity of

relationship between development of service strategy and economics variables.

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# **STUDY FOR THE INVENTORY VARIANCE REDUCTION OF THE PRIMARY DEPOTS OF A PETROLEUM COMPANY**

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## **ABSTRACT**

This paper is to describe a simulation study on the primary distribution of petroleum distillate products, in order to investigate and solve the effects it generates on the overall inventory variance. The study has been conducted inside the logistics department of a large company producing and distributing petroleum products. After all the refinery processes, but before being placed into the final fuel stations by trucks, petroleum products are used to be supplied to intermediate depots by ship. Depending on the structure and the managing of the supply to these depots, the total inventory wants to follow a product-relied target to optimize costs and risks. Reducing the variance of the inventory is for the company an opportunity to reduce the current target by keeping the same risk in terms of safety stocks employed. The objective of the study was to investigate the inventory trends of all the logistics depots with the purpose of understanding which dynamics cause the inventory deviation. All the planning and the operative activities have been taken into account in order to model all the processes involved. Since target and inventory mean values are strongly related, the control of the variance within certain limits, can allow saving storage costs. All the primary supply distribution is relied on stochastic activities (e.g. loading rates) and unpredictable events as weather condition. The capability of the process has passed through a statistical inference made by the support of proper software, to characterize the supply by statistical distributions function relying on the occurrence of specific events. All the study has been supported by the Six Sigma methodology which focalizes on defects' process reduction by the control of its mean square deviation and following the stages of the DMAIC (Define Measure Analyze Improve Control). The first two phases built the AS IS model. By the analysis made with the AS-IS model, ROOT-CAUSES have been determined, the simulation of different TO BE scenarios based on different supply charters conditions have stated how improve the process and the Control phase has followed. The evaluation of the results on a statistical base and all the study itself has helped in understanding inventory variance behaviors. TO BE scenarios results show that variance reduction can be achieved with few changes in the supply management policy.

## **INTRODUCTION**

The inventory management is of course a redundant subject in logistics and its importance in terms of capital employed has increased by the time. Everything deals with product supply and demand: how the final and intermediate products are carried, stored and released to the final customer (how fast, how well, how frequently etc...). In the oil industry where logistics between storages relies on transportation systems in hubs, ports and warehouses, the final and intermediate products often concern big volumes, therefore inventory represents a major investment for many firms and one of the best opportunity to reduce costs and maintain the competitiveness in the current market. Based on the strong relation with operational activities and considering the big challenges already won by the most effectively firms, the inventory trends involve a large scale of operations and need to be studied and controlled by sophisticated methods and tools.

## SYSTEM DEFINITION

In the management of a generic depot there is the need to reserve part of the useful space of the tanks to undrawable bottoms for technical reason and to strategic layers (e.g. Safety Stock). Thus, for any product the inventory normally fluctuates within two operative limit (Min and Max Op). The objective of the supply is to satisfy for each product the demand of the depot within the operative limits and with the aim of being aligned with all the related-targets\* of the products.

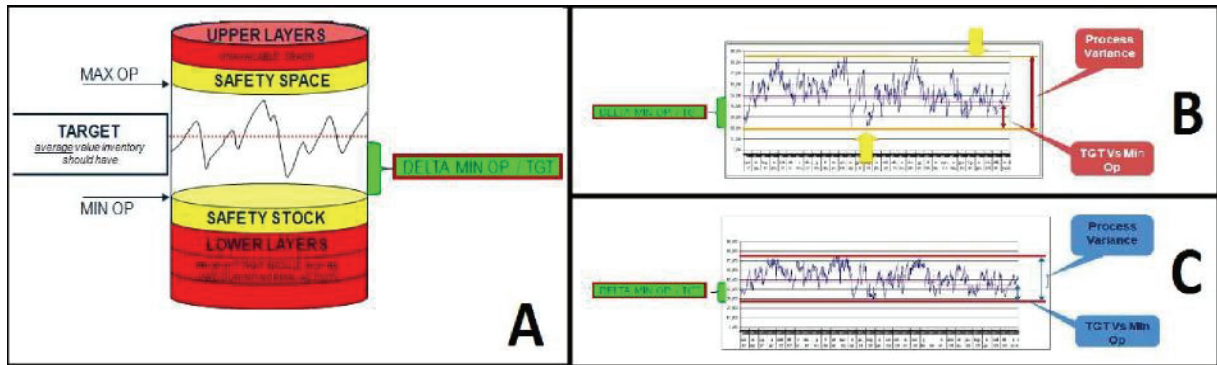


Figure 1

The target makes sure the control of the inventory, in terms of the supply to be in line with the financial and trading statement of the company. Its definition is related to the seasonal changes of the products rather than technical needs (depots/refinery maintenance), demand trend, CSO ministerial duty. The inventory variance around the target becomes important since it affects the DELTA Min Op vs Target (Figure 1). Reducing the DELTA means to have a more controlled supply process and indeed reduce the target, therefore the overall inventory mean value. The objective of the study has been focused on understanding if and how this DELTA could be reduced relying on the current supply system used by KUPIT (Figure 2) in order to obtain the above advantages.

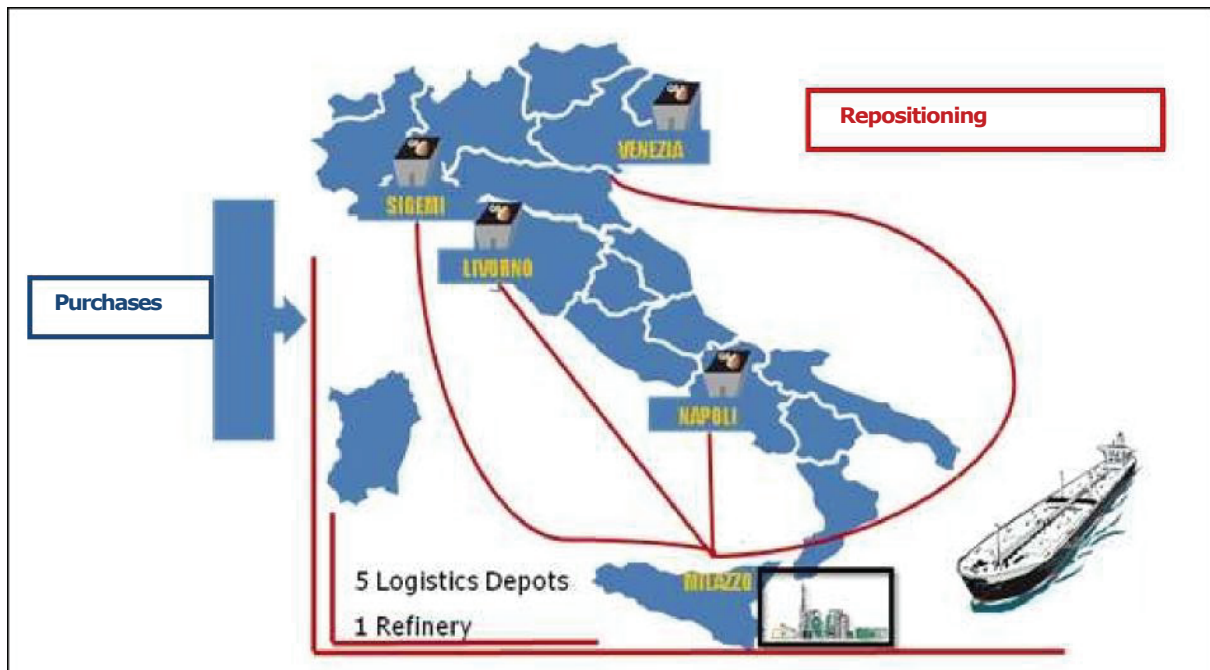


Figure 2

## MEASURE

In order to study the inventory trends different variables have been considered: Inventory trends, final discharging time for each product and each depot, destination arrivals and Round Trip to the refinery, planning data and monthly volumes per depot, vessels' cargo size, depots monthly demand, stochastic input (operational timing). The latter are all the timings which a generic voyage to a specific depot face in order to load the product from the refinery and discharge it at the final depot. Each of these intervals has shown different characteristics in terms of variance deviation from the mean value and their study has resulted very important to understand the capability of the process as whole (Berthing Times, Inspection Times, Voyage Times, Loading Times, Discharging Times). The inference on the stochastic inputs has shown different behaviors and practices during the voyage depending on: which depot has to be reached anytime, what is the cargo composition (which and how many products and which volumes), weather conditions. It has been considered a life span from June 2008 to Feb 2011 and for each sample the statistical analysis has been supported by the software Minitab 16.1.1 and has generated statistical distribution to simulate the real voyages.

CODE	Metric	Mean/StDev	Hystogr.	TRANSF.
X111	(NOR-LAY)<-24	22,38/16,46		<b>B</b> <b>C</b> 
X112	-24<(NOR-LAY)<24	7,37/7,11		<b>J</b> 
X113	24<(NOR-LAY)<48	4,09/5,14		<b>J</b> 
X114	(NOR-LAY)>48	11,96/9,32		<b>J</b> 

Figure 3 - Berthing Time to Milazzo Refinery: process is out of control but can follow certain paths relying on the comparison between planned (LAY) and real arrivals (NOR)

## MODELLING ROOT CAUSE AND SOLUTION

In order to study all the variables involved and understand how the system could react stressing some of them, a stochastic simulation within Arena Rockwell Simulation Software has been placed. The first phase built the AS IS model. All the stochastic distribution and the others Input have been implemented. Outputs have been used to validate the model (discharging times and inventory trends).

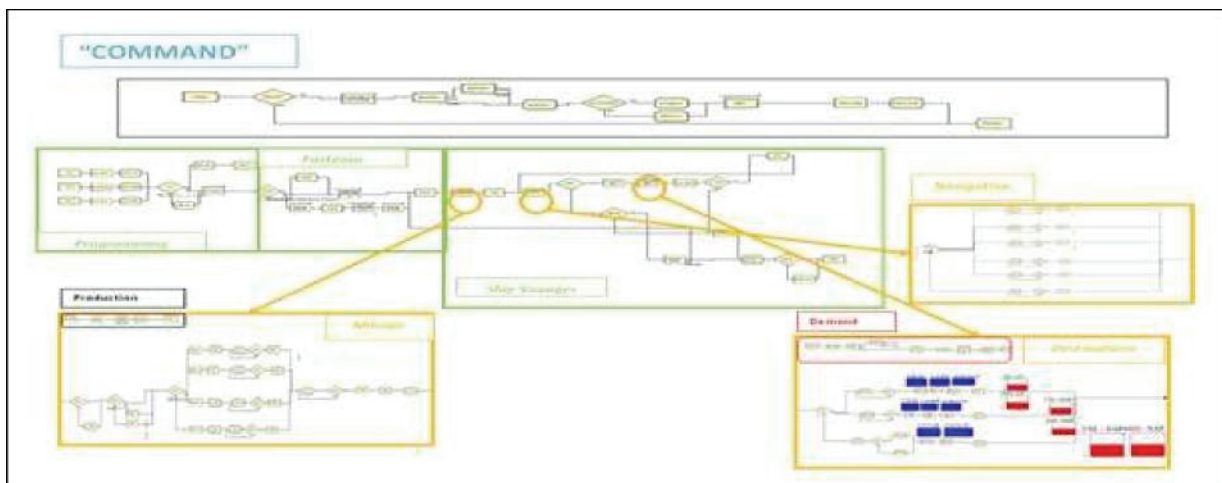


Figure 4 – Part of the Stochastic Model in Arena Development Environment

Different ROOT CAUSES has been found. The following were further analyzed because of their stronger impact and control:

- Domino Effect: Due to consecutive voyages of the principal vessel and to berthing time out of control, the delays are accumulated and increase at every voyage;
- Vessel utilization rate: The high utilization of the principal vessel which make different distance at every depot feeds the Domino Effect and the delay for berthing;
- Vessel cargo and drop size: By different cargo sizes and segregations, the variance of the inventory can be highly affected;

The model phase has followed with the building of different TO BE scenarios:

- Different Purchase strategy in between the depots: with this solution the permanent vessel could be completely dedicated to the principal depot, so that no purchases would be needed.
- 2 Permanent Vessels: This option opens the opportunity of eliminating the SPOT voyages which where necessary to supply all the product to the depots;

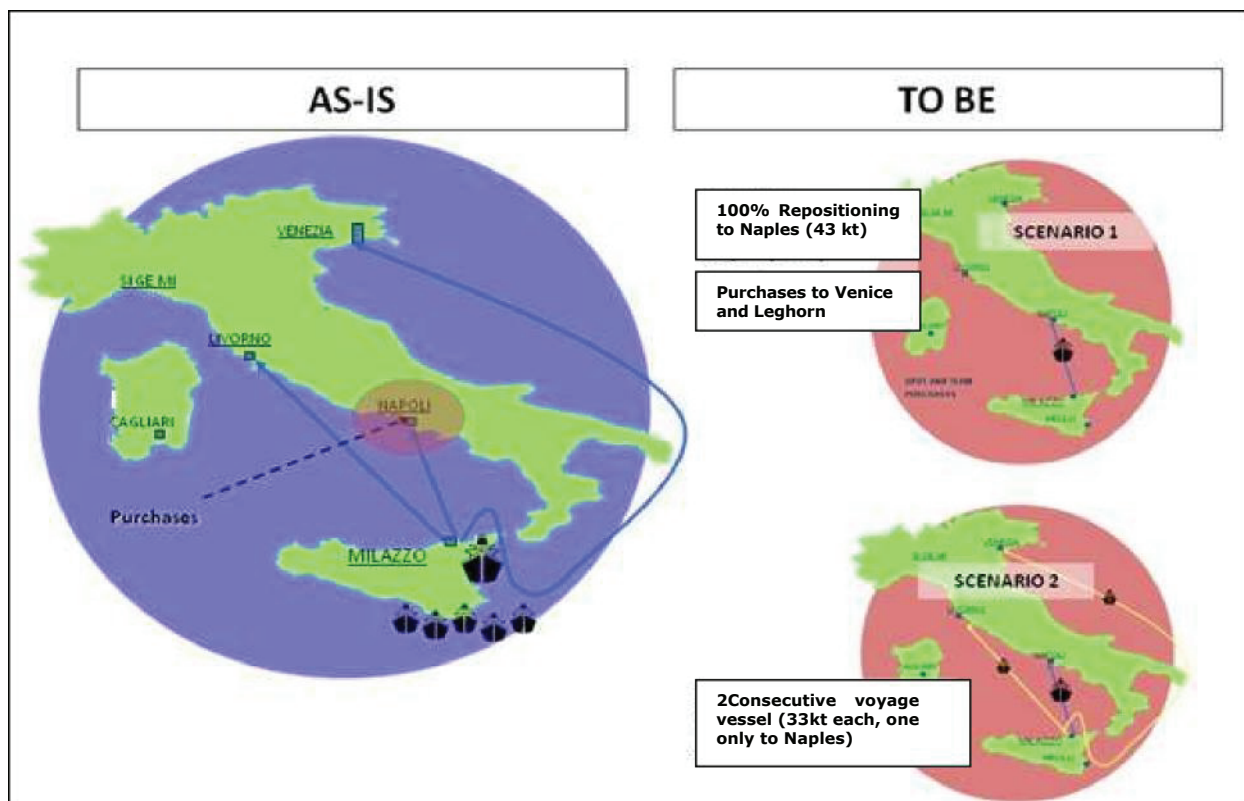


Figure 5 - The Stochastics TO BE Scenarios

## RESULTS

The two solutions have shown similar results. The first one also improved considering different Cargo Sizes. The standard deviation ( $\sigma$ ) against the inventory mean value reduced by 5 kt, which in terms of target reduction means a reduction in the order of  $3\sigma = 15$  kt for each product (Gasoline and Gasoil). The reduction have been compared with the Minimum Operative level to understand its feasibility.

## CONCLUSION

Considering the two proposed solution, the second one was the best in terms of feasibility and economical advantages (some improving were gained by using different cargo sizes). The economic advantage has been compared with the hiring cost for the additional vessel which of course can be higher than the current SPOT strategy. The economic analysis has shown that depending on the SPOT vessel market the solution can be more competitive and give to the supply much more flexibility on a logistical point of view.

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# **ADDING VALUE TO ONSHORE MANUFACTURING: A THEORETICAL FRAMEWORK OF FLEXIBLE SUPPLY CHAINS**

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## **ABSTRACT**

This paper argues for the inclusion of a theoretical framework of onshore strategic flexibility when making decisions about onshore or offshore manufacturing. This study will explore how flexible supply chain activities can add value among Australian fast-changing-good manufacturers (FCGM) to gain competitive advantage within the same business environment where the demand occurs, with the same or better cost and effectiveness compared with offshore outsourcing. We assume that with the flexible supply chain strategy, a firm is able to achieve sustainable competitive advantage, which can be located beyond the border. Propositions will be examined through a qualitative methodology, inclusion of dynamic capabilities (DC) and total cost of ownership (TCO) theories.

Keywords: flexible supply chain management, strategic flexibility, value adding activity, onshore manufacturing, local sourcing, lean and agile principles

## **1. INTRODUCTION**

Environmental uncertainties, volatile economic situations around the world, a fast-moving business environment and customer demand creates the necessity for a quick response to end users, which in turn requires flexible supply chain solutions in the business environment (Christopher and Holweg, 2011). To achieve a competitive priority, manufacturers may need to reconsider their operation and manufacturing or source their products closer to the end-user. The objective of the study is to examine the viability of onshore manufacturing combined with flexible supply chain solutions in the context of Australian manufacturers and reflect on the emerging question: *How can flexible supply chain management add value to onshore manufacturing among Australian manufacturers?* This research is significant as it contributes to academic and practitioner communities as well as government as it develops and empirically tests a conceptual model that investigates how companies could manipulate their resources and capabilities in a rapidly changing environment. This study also provides a valid and reliable understanding of the advantages of onshore manufacturing and business contextual dynamism for customer requirements, and contributes to literature by applying this conceptual model to the Australian manufacturing industry.

According to Stoten (2011) although China and several other Asian countries have become the ascendant manufacturing part of the world, generating the outsourced context, there is a trend among American and European manufacturers to move their operation from low-labour-cost-countries (LLCC) back to their home(Christopher et al., 2011, Stoten, 2011, Moser, 2011). More and more organizations are reconsidering their corporate strategy and relocating their operations as global sourcing drives towards an increase in logistics costs, making supply chain operations more complex, which increases the number of failures and contributes to the potential loss of organizational reputation (Stoten, 2011).

The literature indicates that a high number of manufacturing jobs within Australia are now being outsourced, as Manufacturing Sector lost 12% of its manufacturing workforce in the last four years (2007-2012) (DIISRTE, 2012). Mainly because of the rise in the Australian dollar, over a short-time period, Australia has become a comparatively high-cost country. Whilst offshore manufacturing is a good strategy for lowering costs and prices for the end customer, there are inefficiencies brought about by the shift to local sourcing, such as less flexibility and a slower response to changing customer demands.

## 2. OVERVIEW OF GLOBAL SUPPLY CHAIN TRENDS AND PROBLEMS

### 2.1. Flexible supply chains

These days, the supply chain holds the key to utilising all partners in the chain for the purpose of gaining competitive advantage and serving the end-user efficiently. The concept of flexible manufacturing first appeared in the 1980s, which has made the supply chain become complex and complicated (Candace et al., 2011). Associated with this complexity and the volatile market environment, managers have to deal with increased uncertainty, such as supplier lead time, market demand, product quality and information flow (Candace et al., 2011). Flexible supply chains are able to manage disruptions in supply, adapt to changes in demand, and control customer service levels effectively (Gong, 2008). According to Duclos et al. (2003) supply chain flexibility can be concluded by six types of flexibility, as: operational system, market, logistics, supply, organizational, and information system flexibility. In conclusion, one component identified in successful supply chain strategies is the ability to be "operationally agile". This creates the possibility to configure assets and operations in both products and geographical aspects to react rapidly to the newest consumer trends (Duclos et al., 2003). In today's turbulent business environment, manufacturing flexibility is a dominant competitive weapon for organizations (Candace et al., 2011, Duclos et al., 2003).

### 2.2. Related studies to onshore supply chain

A number of studies have addressed the importance of onshore manufacturing combined with different types of supply chain techniques. The table below summarises various studies relating to onshore supply chain.

Author/Year	Title	Findings
Christopher et al. (2011)	Approaches to managing global sourcing risk	Companies found considerable difficulty in obtaining both delivery on time and the desired quality from their global supplier
Christopher and Holweg (2011)	Supply chain 2.0: managing supply chains in the era of turbulence	Manufacturers should increase their "local for local" strategy, manufacturing in countries that are nearer to their markets
Cagliano et al. (2012)	A decision-making approach for investigating the potential effects of near sourcing on supply chain	Near sourcing is essential when supply chain strategy focuses on core competencies and on achieving improvements in profitability, efficiency, and flexibility
Holweg et al. (2011)	On risk and cost in global sourcing	Many global sourcing venture are in fact not economically viable due to unexpected hidden and dynamic cost
Steinle (2008)	Limits to global sourcing? Strategic consequences of dependency on international suppliers: Cluster theory, resource-based view and case studies	Two contrasting case studies illustrate that contrary to common expectations, a high global sourcing quota does not necessarily improve a firm's competitiveness
William (2009)	International sourcing: Offshore or Near-shore	For some companies and under certain conditions, the best way to streamline supply chains will be to bring sourcing and manufacturing closer to home
Moser and Lang (2011)	Reshoring manufacturing can increase your competitiveness	Along with the advantage of rising LLCC costs and customer recognition of total cost of ownership and increased customer demand for shorter supply chains and faster response will help business to decide reshoring
Duclos et al. (2003)	A conceptual model of supply chain flexibility	Global sourcing is inflexible due to the complexity, thus cannot react rapidly to consumer trends for both products and geographic areas

Table 1. Summary of various studies related to onshore flexible supply chain

### 2.2. Value adding processes in the supply chain context

Adding value to a business process or activity has always had a correlation with gaining competitive advantage (Porter, 1985). According to Porter (1985, p.13), "value is what buyers are willing to pay, and superior value stems from offering lower prices than competitors for equivalent benefits or providing unique benefits that more than offset a higher price". Egan (1993, p. 3) supports this view by stating that "Adding value is the key to long term corporate success". Hence, modifying the production process by adding value increases the final value of the product. Organizations work together in a supply chain for the reason to add value to the end customer. An organization that successfully adds value

is more likely able to operate profitably (Egan, 1993).

### 2.3. Indirect hidden costs of an offshore operation

Initially, global sourcing was utilized for “in-house” operations, e.g. supplying production with materials or goods from overseas. Recently, offshore manufacturing has become the favoured management orientation (Butner, 2010). This direction seems to be effective and provides organizations the possibility to achieve competitive advantage, but in the last ten years, global economic uncertainty and volatility has weakened the benefits of global sourcing as greater risks appear. Notwithstanding, according to Hogg (2003), the total value of an offshore operation can increase total costs by up to 50%. Manufacturers and retailers are at the mercy of international suppliers and in local supply chains become weak because of the tyranny of distance (Pagani, 2004). Although locally manufactured goods cost a little more than their imported counterparts, they are closer in terms of transportation, can potentially provide better quality and are on time. Table 2 describes the cost of offshore operation/global sourcing categorised as direct, dynamic and hidden types of expenses (Holweg et al., 2011, Christopher et al., 2011, Hannon, 2009). Direct costs can be calculated, as its variables are predictable, but dynamic and hidden costs are mostly unpredictable, thus organizations are not able to express these costs in the business plan. To consider all the risks and costs of offshore manufacturing, organizations should make cautious considerations before they decide to send jobs offshore.

Direct cost	Dynamic cost	Hidden cost
<ul style="list-style-type: none"> <li>• High transportation cost compare to local sourcing</li> <li>• Quality problems</li> <li>• Longer lead time</li> <li>• Much higher transportation cost</li> <li>• Customs and duty costs</li> <li>• Transaction and insurance cost</li> <li>• Higher inventory cost due to the long transportation time</li> <li>• Extra cost for managing international business, including extra cost of bilingual professionals, agencies, local personals, travel costs</li> </ul>	<ul style="list-style-type: none"> <li>• Inventory destruction due to long transportation, e.g. in case of quality problems</li> <li>• Increased transportation time and safety stock due to safety stock by demand volatility and variety</li> <li>• Much more investment in inventory due to the long term transportation</li> <li>• High investment due to high quota restriction</li> <li>• High level of carbon footprint emission, environmental risk</li> <li>• Cost of lost sales and out-of-stock due to the delayed transportation</li> <li>• Cost of urgent and expedited shipments, e.g. air freights, to provide continuous supply</li> </ul>	<ul style="list-style-type: none"> <li>• Increased wages in host country due to the rising living standard and market competition</li> <li>• Communication problems due to the lack of personal discussion because of the distance</li> <li>• Lower responsiveness, lost or damaged products</li> <li>• Loss of know-how</li> <li>• Fluctuation on interest rates</li> <li>• Cultural and time difference</li> <li>• Lack of Corporate Social Responsibility</li> <li>• Political and economic instability, possible terror attack</li> </ul>

Table 2. Different costs of global sourcing and offshore manufacturing, adopted from Holweg (2011), Christopher et al (2011), Hannon (2009).

### 2.4. The role of manufacturing sector in an economy

Manufacturing has an important role in the economy and the development of a country. In numerous cases the manufacturing sector contributes primarily to the modernization and the expansion of a country (ABF, 2011). There are hardly any examples of countries with high living standards where the manufacturing sector did not significantly contribute to economic output (ABF, 2011).

### 2.5. Governmental taskforces

Within Australia, the government established a taskforce (DIISRTE, 2012) to explore Australian manufacturing (issued in July 2012). The report stressed the importance of keeping Australian manufacturers within the country, and although proposed several suggestions, few seem to be realized. Similarly, the outcomes of the taskforce focused largely on government support and intervention, but did not propose a business strategy as a “self-sufficient organizational fulfilment”. This research will provide more insight into areas that government highlighted as part of this taskforce in identifying the advantages of onshore manufacturing. Moreover, In U.S., Congressman Wolf (R, VA) has launched the “Bring Jobs Back to America Act” (H.R.516) in 2010, inclusion of the Total Cost of

Ownership concept. Hence, there is great government support to reshore productions with additional support with industry articles, webinars and presentations. An integrated five-step "Illinois Reshoring Initiative" has been launched with the assistance of a Total Cost of Ownership software to calculate the real cost of offshoring with hidden costs (Moser, 2011). In this regard, total cost of ownership calculation seems to be sufficient enough to achieve reliable answers to the propositions of this study.

### **3. THEORETICAL FRAMEWORK**

The study will be grounded in Dynamic Capabilities theory (DC) and Total Cost of Ownership (TCO) analysis. Originally, Resource-Based View, Transaction Cost Analysis and Porter's Five Market Forces were considered to support the basis of this study, but Dynamic Capabilities and Total Cost of Ownership theories appear to be more relevant to make viable answers for the propositions of the study.

(Teece et al., 1997, p. 516), define dynamic capability as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments". In the last two decades rigid competition has driven organizations to reconfigure and re-create their resources and capabilities regularly. The basic assumption of the dynamic capabilities framework is that "core competencies should be used to modify short-term competitive positions that can be used to build longer-term competitive advantage." The literature on dynamic capabilities grew from the resource-based view of the firm and the concept of "routines" in evolutionary theories of organizations (Teece et al., 1997). The best manufacturers in the international marketplace were well-known for their time responsiveness, swift and flexible product innovations, along with the executives efficiency to arrange and assort external and internal competencies (Teece and Pisano, 1994).

Resources can be identified as the foundation of an organization and the basis of the firm's capability, however alone it is not able to serve the fundamental of competitive advantage, because, for instance, in a fluctuating market environment resources only exist over a period of time (Wang and Ahmed, 2007). But when firms expose their capabilities by arranging resources, they most likely will improve their achievement. This combination of resources and capabilities are the core capabilities of an organization that can help an organization outperform their competition. "Hence, the dynamic capabilities emphasis a firm's constant pursuit of the renewal, reconfiguration and re-creation of resources, capabilities to address the environmental changes" (Teece et al., 1997, p. 11)

The Total Cost of Ownership (TCO) concept was originally developed in 1987 to assess IT investments and has since been discussed and adapted by several authors for their specific needs (Bremen et al., 2007). As Ellram and Siferd (1993, p. 58) stated "to evaluate a sourcing decision, all costs associated with the acquisition, use and maintenance of a product are taken into consideration". Experts have long emphasized the importance of looking beyond the price to enclose the transaction costs in purchasing from external sources. Originally, executives implemented TCO to achieve better results in a make-or-buy decision (Ellram and Siferd, 1993), whereas other researchers apply TCO for supplier or vendor selection (Weber et al., 2010, Degraeve et al., 2005). TCO originated from transaction cost analysis that helps organizations to understand their true cost of purchasing or sourcing (Ellram and Siferd, 1993).

Traditionally, the actual prices of goods were the primary factor when choosing suppliers or deciding on outsourcing (Weber et al., 2010). However, firms became more and more strategically aware of the importance and relevance of indirect and hidden costs in international sourcing. As a result, decision makers have started to venture into the numerous indirect and life-cycle costs besides the certain prices of goods and services from partners overseas (Ellram et al., 2008). Although literature has highlighted the importance of TCO, industry based practice of the theory can be barely experienced, however, applying TCO to purchasing, outsourcing or offshoring decision would give organizations the possibility to exploit TCO in value analysis (Zachariassen and Arlbjorn, 2011). Extending

this view, Weber et al. (2010), Moser (2011), state that Total Cost of Ownership is also favoured in comparing onshore and offshore manufacturing. The following practical example expresses the importance of TCO, as in the US, the 'Reshoring Initiative', supported by the US government, invented and expanded a free online TCO calculator for the purpose of examine the real cost of an offshore manufacturing (Moser, 2011). Basement of the activity and the achievements of Moser and the Reshoring Initiative, in this research TCO analysis will be conducted to study true cost and cost drivers to assign indirect costs of an onshore operation. In case when TCO is not specific enough to identify the real cost of an offshore related expense, following Weber et al. (2010) suggestions, activity base cost (ABC) analysis will assist TCO to identify the real cost drivers of an offshore operation.

Table 3. proposes a theoretical framework connected with the literature and theories

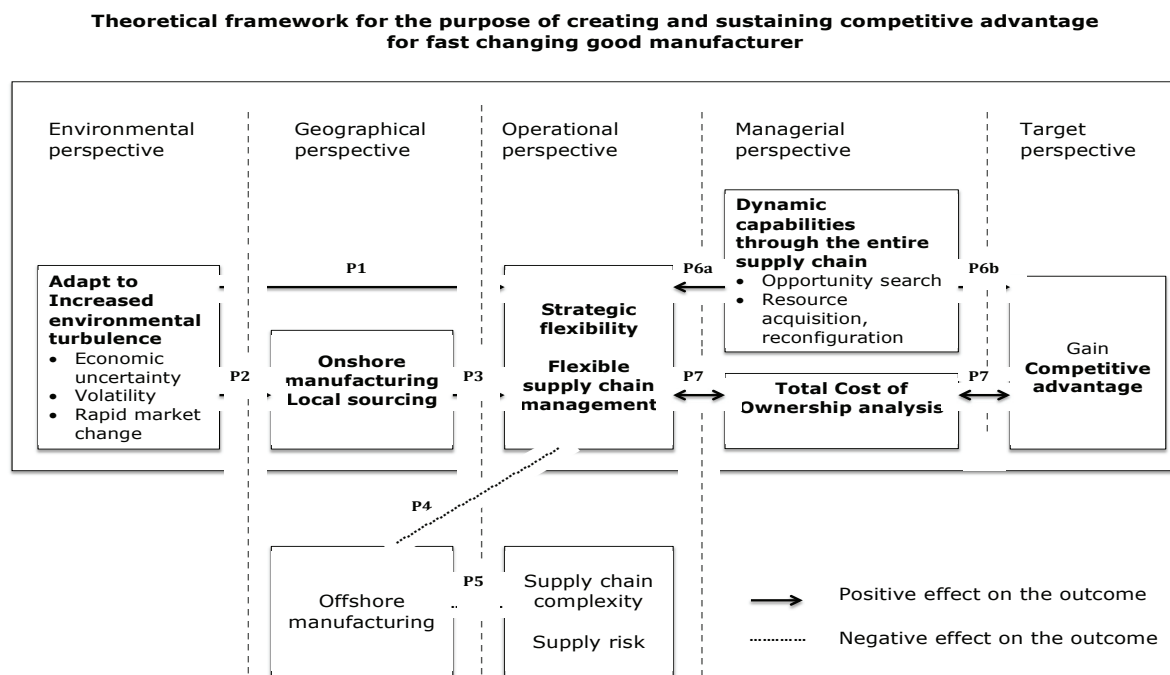


Table 3. Theoretical framework

In the next section, research propositions will be demonstrated connected to the theoretical framework above.

### 3.1. Research Propositions

There are many possibilities in which an organization can gain competitiveness, but in a turbulent market environment strategic flexibility is required. Because the direction of expansion is obscure, firms need to implement flexibility in terms of renewing existing resources, changing their resource position and refreshing their capabilities to be able to adapt to changing customer demand (Smith and Grimm, 1987). "Strategic flexibility requires organizational routines to reconfigure a firm's resources to respond to specific environmental changes" (Zollo and Winter, 2002, p. 4). By maximizing the productivity of a certain set of resources, firms will learn and gain competitive advantage from the contribution of new resources (Zollo and Winter, 2002).

**Proposition 1:** There is a positive relationship between increased environmental turbulence and the likelihood that firms will become aware of the need of flexibility, i.e. repeatedly reconfigure resources and capabilities in order to remain competitive.

Toyota still produces its cars in Silicon Valley, the most expensive place on Earth. The reason behind this decision is to be efficient enough to produce goods close to the places

where demand occurs, even when labor costs are high (Ritter and Sternfels, 2004). Many companies believe that sourcing goods from low labor cost countries is still viable, although they overestimate the savings and do not realize the negative effects, such as dealing with exchange rates, obsolescence, inventory and many other dynamic and hidden costs. When competitive advantage comes from speed and a track record of reliability, offshore manufacturing often is not the right strategy. According to Ritter and Sternfels (2004) these days, speed has become a competitive weapon and it can create a trap if a supply chain becomes complex, robust and slow.

**Proposition 2:** The more rapid market and competitive conditions change, the more likely it is that a firm will rely on local sourcing and onshore manufacturing, i.e. the more close production is to the market place, the quicker end-user response can be achieved.

Recently, global economic uncertainty and volatility has weakened the benefits of global sourcing as greater risks appear (Butner, 2010). Furthermore, associated with distance, supply chains are becoming more complex, costly, and vulnerable. Although product prices are much lower in Asian countries, supply chain complexity, difficulties of supply and logistics, volatility in the business environment and several other aspects, lower the benefit of international sourcing (Butner, 2010). International sourcing and offshore manufacturing can result in bigger investments due to long transportation, and it can create several hidden costs (as Table 2 describes).

**Proposition 3:** Offshore manufacturing and local sourcing is negatively related to successfully serving a flexible supply chain.

According to Prater et al. (2001) global sourcing has an intention to increase complexity, which works against agility. Even if high-level agility has been implemented in the supply chain, flexibility is impossible due to a complex global sourcing strategy with large time lags and variability in delivery. Complexity may arise from physical distances as it increases transportation and order demand forecast (Prater et al., 2001). According to Forrester Research (Radjou, 2000), high level of inflexibility can be observed in the global production environment. The inadequacy to transfer goods from one plant to another and the inability to successfully respond when capacity is constrained makes global manufacturing inflexible. Furthermore, increasing risk in global business is made more difficult through the supply chain.

**Proposition 4:** The greater the reliability in global sourcing, the more chance to demolish agility and flexibility

In recent supply chain trends, for markets that are increasingly interconnected, outsourcing or offshoring are more common, which enables companies to concentrate mostly on their main competencies (Liu et al., 2010). Nevertheless, emerging risk can impact the benefit of global businesses, weaken companies' reputation and damage competitiveness (Liu et al., 2010). As reported by Christopher et al (2011), poor synchronization in the supply chain is frequently caused by outsourcing and offshoring decisions. Furthermore, product complexity (variance on components, suppliers, transportation paths), communication failures, misunderstanding product requirements seemed to be the key risk of global sourcing (Christopher et al., 2011). Uncertainty and complexity increases external vulnerability. Logistically difficult geographic regions and the number of regions covered by the supply chain increase uncertainty and supply chain exposure. Each political area or border that a supply chain must cross can pose problems. (Prater et al., 2001).

**Proposition 5:** There is a positive relationship between supply base complexity and supply risk that the focal company assumes when working with its offshore outsourcing supply base.

Supply chain partners must possess a culture of viewing the supply chain as a whole and of recognizing the need for cooperative efforts. Sophisticated organizational and strategic routines are the basis of dynamic capabilities (Zollo and Winter, 2002), which assist in rearranging and refreshing resources along the supply chain to make viable economically

value-creating strategies. Thus, these capabilities are the elementary drivers of the configuration of other resources to provide new possibilities of growth (Mentzer, 2004). The collaboration that an effective supply chain result can assist in creating new cross-organizational capabilities that makes supply chains more competitive and less vulnerable to competitors that are less effectively actualize innovative capabilities (Mentzer, 2004).

**Proposition 6a:** The greater the dynamic capability of a supply chain, the greater it can utilize strategic flexibility, and the more effectively it can engage in resource configuration.

**Proposition 6b:** The greater the expansion of dynamic capabilities to multiple organizations in a supply chain, the greater the possibility to successfully add value and gain competitive advantage.

Combining flexible supply chain management with the advantage of rising LLCC costs and customer recognition of TCO and increased customer demand for shorter supply chains and faster response will help organizations to gain competitive advantage (Moser, 2011).

**Proposition 7:** The greater the reliability on flexible supply chain management the greater the possibility that after TCO calculations the organization prefers onshore manufacturing for the purpose of achieving competitive advantage.

#### **4. RESEARCH METHODOLOGY**

From the perspective of the objectives, this research is classified as an exploratory case study that will be conducted via a qualitative method. "A qualitative case study captures the reality of a given situation in substantial detail and is particularly useful when a natural setting or a focus on contemporary events is required" (Yi et al., 2011, p. 273). Semi-structured interviews will be the main data collection process for this research supplemented by surveys as a method to broaden the view for generalization and support the result of the interview phase. The data will be collected among five-to-ten offshore and five-to-ten onshore Australian fast-changing-good manufacturers and two-to-five government members. Paper and online-based surveys with close-ended questions will be conducted among 150-200 FCGMs and analyzed via descriptive statistic.

#### **5. CONCLUSION**

This paper addressed the issue of the possible limit to operate efficiently and serve customer demand without constraints in offshore environment. The literature indicates that firms optimizing opportunity through global sourcing may not be viable in several instances. Local sourcing/onshore manufacturing is essential when supply chain strategy focuses on core competencies and on achieving improvements in profitability, efficiency, and flexibility. Furthermore, manufacturers should increase their "local for local" strategy, considering that numerous global sourcing ventures are in fact not economically viable due to unexpected hidden and dynamic cost. Global sourcing is inflexible due to the complexity, thus cannot react rapidly to consumer trends for both products and geographic areas. The theoretical contribution of this paper is the integration of both the dynamic capabilities approach and the total cost of ownership analysis into the management and supply chain domain in general, and into the onshore or offshore operation debate in particular. This research is significant as it contributes to academic, practitioner communities as well as government, as the outcomes of this research not only provides an exploratory foundation for the future research on the subject of flexible supply chains, but also reveals the procedure of generalizing a conceptual model in a particular situation context.

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# **A REVIEW OF THE LATEST DEVELOPMENTS IN WAREHOUSING AND MATERIALS MANAGEMENT**

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## **ABSTRACT**

This industry-focused paper discusses materials management developments and opportunities for further improvements. We start with a review that describes how material handling has for a long time been an enabler of logistics in that it enables companies to fulfill supply chain demands. As companies need to handle ever more volatile demand profiles and increasing variety, the processes and systems that underpin this must be stable in order to achieve the overall logistics goals. Here an example from the food retail business is used to demonstrate the increasingly demanding requirements for materials management and handling systems. The consequences of this include the fact that ever more intelligent tools and strategies are required to service these requirements and that the new generations of handling systems need to be increasingly innovative. Such an approach is offered by 'Industry 4.0' - a strategy to make production and production logistics fit for the future.

## **BACKGROUND**

Companies today are faced with pressure for a continual reduction in inventories along the whole supply chain, together with an increase in the number of stakeholders (suppliers, customers, etc.) On the other hand globalized competition leads to increasing 'price struggles'. Additional aspects also need to be considered (Dullinger, 2008; ten Hompel and Schmidt, 2010). These include the following:

- Speed is one of the unique selling points (USPs) in all kind of business
- Increasing capacity is needed (both static and dynamic capacity)
- Ever more volatile conditions are being experienced – making forecasting more difficult
- Increasing quality is demanded - due to more integrated supply chains
- Higher levels of standardization are required - due to globalized applications

These factors together lead to a significant increase in complexity, which in turn needs to be managed efficiently and effectively.

## **MATERIALS MANAGEMENT AND HANDLING SYSTEMS - OVERVIEW**

Figure 1 lists some of the key logistics requirements in the food retail business. Each of these has a strong bearing on materials management, as well as on handling systems. The food industry is characterized by short delivery cycles and a need for highly optimized transport solutions. This is supplemented by an ever-increasing range with a corresponding increase in categories and part numbers.

- shorter delivery cycles (sometimes several times per day)
- smaller quantities
- increasing assortment in food retail in general (more and more categories and doubling of part # in the last 15 years)
- freshness in shelf
- sequence requirements for picking (family grouping according layout of PoS, heavy before light, etc.)
- reduced inventory and time savings by use of cross docking
- efficient returns logistics(transport in reusable LU, repacking, ect.)
- sustainable solutions
- intelligent packaging (few lost space but secure, avoiding theft / mis-use)
- and finally: all processes for transport or for picking must be “travel way-optimized” either for man or for machine

Figure 1: Indicative logistics requirements in the food retail business

These conditions demand greater efficiency in warehousing and distribution. This can be summarized as follows:


- The main goals are reduced inventories and lead times. This will be enabled by strategies such as cross docking, vendor managed inventory, etc.
- Sequence requirements, such as optimized travelways in POS according to individual store layouts and structure of the categories or weight aspects (i.e. heavy before light).
- Sustainability requirements heavily influence all parts of business. Therefore efficient returns management and intelligent packaging solutions are needed.
- Travel route optimization is a must, for both personnel and for machines.

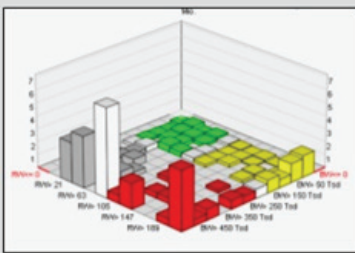
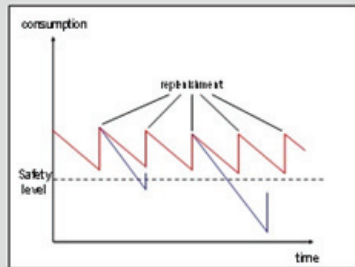
### **TOOLS AND STRATEGIES FOR PROCESS OPTIMISATION**

In terms of inventories, attention should be paid to two main aspects:

- According to the EOQ-diagram inventories should be in balance between the savings in purchasing due to large scale effects and the costs of inventories (finance aspects, warehouse investment costs and associated operational costs such as longer travel routes, etc.)
- The inventories should be in balance between replenishment lead time and consumption / demand. To be 'out of stock' is a fundamental error and should only occur in extreme circumstances. Therefore a minimum level of stock should always be available. This should be the case along all stages of the inventory pipeline i.e. in the company's own warehouse, in the supplier's warehouse or in transit along the transport network.

How large this reserve stock has to be, depends on the demand and degree of fluctuations. In any case, the inventory reserve has to be able to take into account unforeseeable situations. Another essential requirement is the flexibility to react very quickly to changes. This is possible only when the lead times of all processes are reduced to a minimum.

How can we reduce stock?  **Many measures**




- Minimize safety level (& reduce risks by second source)
- Shorter replenishment cycles with reduced quantities
- Reduced lead time (& reduced inventories) (lean production, KanBan, JIT/JIS, Cross Dock, „call off orders“ based on blanket order, etc.)
- C-parts management based on sensor technologies
- Production supplies based on set picking, tug trains, etc.
- Pull principle, ECR, VMI, pearl chain strategy
- Harmonized stocks in SC
- Diversification of a product in final step of process enables reduction on stock with finished goods (high value goods)
- Analysis abnormal inventory situations
- Virtual warehouse / better balancing central/regional DC
- Flexibility in distribution (variable flow DC-POS, POS-POS)
- Precise planning (use of suitable tools)
- Sort out of „dead stock“

Figure 2: measures to reduce inventories


Naturally, if replenishment can be organized like a “pearl necklace” the range in your store, production buffer, etc. can be reduced to a minimum. Tools are now available that enable full transparency of customer demand. Some even make suggestions as to which replenishment strategy is the best. The tool “value stream design” is very powerful when processes need to be optimised. If processes are designed according to this method, wasted time (MUDA) becomes much more clearly visible within the process. JIT/JIS strategies have become much more popular beyond the automotive industry, owing to the benefits that can be achieved in terms of lead time and inventory reduction. As shown in Figure 3, new sensor technologies now enable an efficient supply of C-parts to assembly stations.

### C-parts Management with automated replenishment

Supported by use of RFID



Supported by use of camera based recognition & RFID

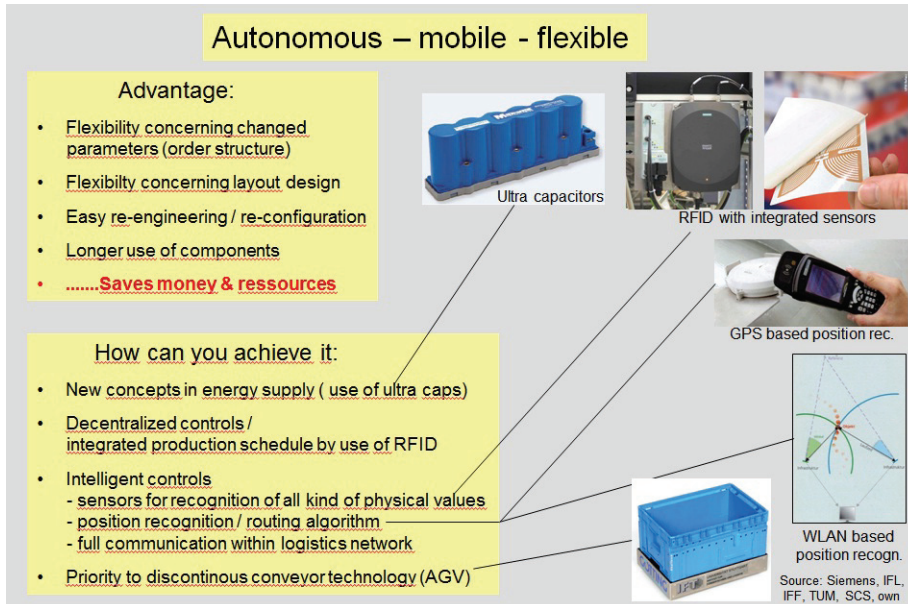


Source: Ferrometall, Keller & Kalmbach, Würth

Figure 3: Advanced Kanban System

## SYSTEMS DESIGN ASPECTS OF MATERIALS HANDLING SYSTEMS

The lifespan of materials handling systems often exceeds 20 years (and substantially longer if retrofits are undertaken). If we want to design systems that are able to fulfill increasingly volatile demand patterns and also reduce supply chain risks, etc., the system design has to be flexible. How increased flexibility can be achieved is shown in Figure 4. Besides flexibility many other characteristics are required (i.e. sustainability, ergonomic working condition, intelligent user interfaces, etc.).



*Figure 4:  
Flexibility  
characteristics*

As indicated at the start of the paper, supply chain complexity is increasing. To better manage this complexity two components are needed - a powerful Supervisory Control and Data Acquisition (SCADA) system to achieve more transparency and an intelligent Condition Monitoring System (CMS). Owing to space restrictions, we advise you to obtain further information on this from Dullinger (2011).

## CONCLUSIONS AND FUTURE OUTLOOK

The insights from this paper can be summarized as follows:

- Intelligent materials handling systems are fit for the future and will enable supply chain efficiency.
- Intelligent materials handling optimizes processes, making materials management easier and more efficient and hence enables greater supply chain management efficiency.
- Automated solutions will have all the characteristics required to become much more efficient than manual systems, therefore the percentage of fully automated systems will greatly increase.
- Industry 4.0 will help European production and logistics companies to compete with those in more cost competitive emerging markets.

The implications to researchers in this field are that innovation should remain at the heart of materials handling in order for European firms to remain competitive in the global marketplace. The developments and applications outlined in this paper have indicated that material handling systems will be a strong enabler to handle future challenges. In any case there will be some design rules that are always "up to date". These include; keep it as simple as possible, lean material flow is always a challenge, added values / USP`s to the customer/user are a must, efforts for improved quality costs money but it is always worth doing. Last but not least one needs to bear in mind that new innovations appear all the time. In terms of future supply chain aspects, we can summarize that tools for optimized materials management can provide strong management support, intelligent material handling is a holistic approach and reduces (among other things) complexity, resources and overall costs. This paper has provided an overview of some of the many developments that have been recently launched into the market. *Indeed intelligent material handling components are already part of 'Industry 4.0' - a strategy that seeks to make production and production logistics fit for the future.*

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# **EXPLORING THE FEASIBILITY OF HORIZONTAL COORDINATION IN ROAD BASED LOGISTICS**

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## **INTRODUCTION**

As the commercial pressures on the provision of logistics intensify the desire to question all wastes involved in the logistics process continues to mount. This has contributed, especially in recent years, to a renewed focus on the potential benefits than can be gleaned through exploiting horizontal coordination and horizontal collaboration in logistics, even with an organisation's competitor. Horizontal coordination in logistics can be defined as, "voluntarily initiated, long term relationships among autonomous logistics service providers that operate on the same stage of the supply chain as close or distant competitors and that strive for benefits that could not be achieved by individual companies alone" (Schmoltzi and Wallenburg, 2012). In air and sea based logistics, horizontal coordination has been a characteristic of their sectors for some time, but for road freight logistics this is, surprisingly perhaps, a fairly recent phenomenon (Crujssen et al, 2007).

However, whilst many organisations appear to be happy to progress into this relatively new area of logistics coordination and collaboration, for others, especially including many large shipper customers of logistics providers, there would seem to be a reluctance to embrace it. This research focuses on this issue. In this paper we examine the strategy and operation of a shipper responsible for large volume road freight movements across Europe and explore to what extent embracing enhanced horizontal coordination and collaboration in logistics would be aligned or contradict with their core supply chain strategy goals. In reality, the feasibility of a new idea is often the key to its level of adoption. Consequently, the fit with a shipper's strategy is an important area to research in understanding the take up and consequent impact horizontal coordination and collaboration in logistics (HC) may have in the future in such areas.

The research builds from an initial exploratory survey which revealed that there was a difference in awareness between shippers and providers of HC. Given, shippers are the customers of logistics and thus have a role to play in the logistics services they contract, it was considered important to learn more of shippers' attitudes to HC. A case study methodology was then chosen as the most appropriate method to examine these issues. A leading shipper based in the UK, from the fast moving consumer goods (FMCG) sector, was selected. The research was based on semi-structured interviews with leading decision makers in their logistics and supply chain operation with a focus on how the main flows of product sourced from continental Europe, notably Spain, were managed. This involved a mixture of goods, mostly food-based, with a variety of perishability levels. This operation and the strategic demands the shipper insists on was then reviewed in relation to the feasibility of enhancing HC in this area.

The paper is structured as follows: first a review of the literature describes how HC has become an area of research focus and practitioner interest in recent years, but is still at a fairly embryonic stage compared to research on vertical collaboration, for example. The exploratory research, which revealed a difference in attitude on HC from the perspectives of the shipper and provider, is then briefly presented, before the core methodology used in this study is explained. After the results are set out, the analysis section examines the feasibility of HC from this shipper's perspective. Finally conclusions are drawn and a set of questions for future research in this area is put forward as a key contribution of the paper.

## **LITERATURE REVIEW**

In modern supply chains, in many sectors, the demands to reduce inventories, whilst maintaining or achieving higher and higher levels of product availability for customers are placing considerable pressures on the logistics function (Skjøtt-Larsen, 2000). In summary, the lean, low inventory supply chain, discernible now in many industries, is demanding robust logistics services. These services are characterised as being highly responsive, capable of delivering orders more frequently in smaller batches, with consistent delivery quality, which can be relied upon day after day, month after month and year after year. Many industries exhibit such characteristics desired from its logistics processes, such as the automotive, electronics and grocery sectors, to name but a few.

To combat these pressures many innovative business models and operational strategies have been enacted upon by logistics providers, notably through exploiting developments in technology and/or using enhanced forms of collaboration. For supply chain management (SCM) advocates the core idea is to encourage the synchronising of the supply chain through intensifying integration via vertical collaboration (e.g. Stevens, 1989 and 1990). Uncertainties, it is argued, can be removed from the chain of supply, smoothing, where possible, material flows. Logistics providers as the link provider between the product seller and buyer can therefore be seen as integral cogs in the chain of supply and thus act as crucial supporters and even facilitators of modern SCM (Skjøtt-Larsen, 2000, Mason and Lalwani, 2006, Stefansson, 2006 and Naim et al, 2006).

However, the providers of logistics are increasingly realising that there are still many wastes in their operations if they are left to be dedicated to serve specific supply chains. This is leading to a renewed focus for them to consider what can be gained by coordinating logistics activities in support of one chain with other parallel chains of supply. This exploitation of horizontal coordination, often through horizontal collaboration, even on occasion with competitors (Bengtsson and Kock, 2000), where assets in logistics, such as a truck or a warehouse are positioned to serve numerous parallel supply chains and not exclusively focused on one supply chain is becoming an attractive area to explore and exploit. Logistics providers are therefore juggling vertical and horizontal inter-organisational relations at the same time (Caputo and Minimo, 1996 and Mason et al, 2007)

There are potentially many benefits in pursuing HC in road freight logistics. Cruijssen, et al.,



(2007) suggest that these benefits stem predominantly from generating "relational rents", citing Dyer and Singh (1998), who define as "a supernormal profit jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through the joint idiosyncratic contributions of the specific alliance partners". Cruijssen, et al., (2007) propose three categories for HC benefits: "costs and productivity benefits, service benefits and market position benefits". Mason et al., (2007) largely concur with these, categorising them as benefits of "efficiency, asset utilisation and customer response".

Cost benefits can accrue from being able to more intensively use core assets, such as trucks or warehouses. Empty backhauls can be reduced or eliminated and a better use of the trailer cube can be pursued by linking logistics requirements of different supply chains. In addition, non-core activity costs can be reduced by sharing them between organisations at the same level, such as for training, providing joint fuelling arrangements or joint purchasing of vehicles, fuel or consumables.

Service benefits largely occur as the logistics provider can afford to offer more frequent deliveries and cover wider geographic areas. Market benefits are derived from the fact that logistics providers can join together to tender for contracts that on their own they would be unable to consider.

For the most part Cruijssen et al., (2007) and Mason et al., (2007) consider the benefits from the logistics providers' perspective. It is important however to consider HC from the perspective of the shipper too. For example, the service benefit of being able to provide more frequent deliveries is important in the modern supply chain where the level of working capital tied up by shippers as inventory is being questioned. More frequent deliveries, enabled by enhanced HC, allows shippers to lower inventory levels and benefit from the speedier recovery from poor availability scenarios, which may occur. In addition, shippers are being challenged to act responsibly from the wider sustainability agenda and HC has numerous benefits in this regard, such as allowing for lowering of emission rates through, for example, a more intensive use of assets, or a lowering of inventory levels.

There are, as well, a range of recognised impediments, or barriers, to HC. Again Cruijssen et al., (2007) identified a number of these, which were categorised under the headings of "partner selection problems, determining and dividing the gains, the unequal negotiating positions of partners and the uneven adoption of information communication technology solutions among logistics providers". Wallenburg and Raue (2011) pick up on some of these arguing that there are inherent governance issues surrounding HC which can lead to real problems of conflict. This largely stems from their natural high levels of complexity in HC (Schmoltzi and Wallenberg, 2009) and thus great effort needs to be directed towards making such arrangements functional and fit for purpose they argue. Wallenburg and Raue (2011) view that "compared to vertical cooperations, higher potential for opportunism and dysfunctional conflicts emerges as partnering firms are competing for the same customers".

However, again, the literature on the impediments to HC is largely considered from the

perspective of the provider rather than the shipper. From the shipper’s point of view little has been studied in research papers around the subject of the challenges faced from the shippers view if HC is pursued. In addition, HC, as it is defined most simply as, “concerted practices between companies at the same level(s) in the market”, presumably means that HC does not have to exclusively reside in occurrence between providers of logistics: shippers themselves may wish to enter into HC together in efforts to better manage the logistics operations that jointly serve them.

**EXPLORATORY STUDY**

One of the triggers for this research was derived from the results of a survey undertaken with an audience of professionals connected to the logistics industry at a recent logistics research dissemination conference organised by the authors. Of the 41 delegates from industry attending, 42% claimed they were providers of logistics, 29% customers of logistics and 29% were classed as “other”. An interactive clicker system was used to gain the audience’s response to questions posed. One of the questions asked these industrial members of the audience whether, “in their recent experience of logistics provision, did they feel that logistics service providers had shown more / less interest in exploring initiatives which involved HC?” A second question asked whether “shippers had shown more / less interest in HC?” The results, summarised in Table 1, show a clear difference in interest between the two groups, with logistics service providers showing more interest on average than shippers: 73% felt logistics service providers had shown either more or substantially more interest in HC in recent years, compared to only 43% of shippers.

The gap identified in the literature review in the research around investigating the motives and barriers to HC from the shippers’ perspective and this survey result, which appeared to show less interest from the shippers’ perspective than the logistics service providers in HC, led to the main question in this research study:

- o **to what extent is HC compatible with a shipper’s supply chain strategy?**

	Substantially More Interest	More Interest	No Change	Less Interest	Substantially Less Interest
In Recent Years, Have <b>Logistics Service Providers</b> Shown More / Less Interest in HC?	20%	53%	22%	5%	0%
In Recent Years, Have <b>Shippers</b> Shown More / Less Interest in HC?	8%	35%	51%	6%	0%

**Table 1:** Response to the questions, have logistics service providers and have shippers shown

more / less interest in exploring initiatives which involve horizontal collaboration in recent years.

## METHODOLOGY

The chosen method was a case study methodology. This was felt to be most appropriate as it was important to be able to study the issues in some depth. Case studies are also useful in examining the relationship between two variables (Yin, 2009): in this case, whether the strategy of a shipper is compatible with a taking on a more enhanced HC logistics solution.



**Figure 1:** Map of Western Europe indicating the key produce growing region in Spain and the main alternative routes to the UK:

- by short sea shipping connections (after a road leg from Southern Spain) from Bilbao in Northern Spain, either via Liverpool or on a return leg to Rotterdam (after container shipments are moved on the primary leg in the opposite direction) calling in at one of the ports in the South East of the UK;
- by rail moving product from Southern Spain through France, via the Channel Tunnel to the UK
- by road, again moving product from Southern Spain through France, via the Channel Tunnel to the UK. Ro-Ro (roll on, roll off) ferry is more frequently used on the Channel crossing as it is cheaper (this is the principal method currently deployed)

The case study selected was a major Fast Moving Consumer Goods (FMCG) retailer operating in Western Europe with a focus on one of its principal geographical shipment routes across Europe – the Southern Spain to UK trade lane. This route principally concerns movement of fresh produce and wine products. The company was selected as it controlled a substantial flow across a large geographic distance across Europe, was based in Western Europe, which Cruijssen et al., (2007) suggest is one of the leading areas in the world for the development of HC, and was from the grocery sector, which again is considered to be one of the sectors at the forefront of logistics and supply chain development. Thus, given that these criteria were met, the company selected was considered to be an appropriate exemplar case as recommended by Dinwoodie and Xu

(2008).

Data collection methods included semi-structured interviews with decision makers and logistics planners at the shipper and the analysis of shipment data. This multi-method approach allowed for a mix of quantitative and qualitative data to be gathered to strengthen the robustness of the findings, as suggested by Kengpol and O'Brien (2001).

Although the main route used was direct by road from Southern Spain to the UK, other routes were discussed in the findings, as indicated in Figure 1.

## **MAIN FINDINGS**

The shipper was the customer (rather than the supplier) of the supply chain, ordering frequent (daily) shipments of product from Spain for the UK, notably both perishable, temperature controlled short-life produce items and ambient product, especially wine. Spain has a number of key growing regions: Almeria (cucumbers, peppers), Mercia (broccoli, lettuce), and Valencia (citrus), with wine coming from many parts of the country, but most from the central belt. Some products could be transported together to make a full load (e.g. broccoli and lettuce), others could not (e.g. cucumber and peppers). Most produce was destined for a "packhouse" operation in Kent in the South East UK. The perishability of the product is an important factor. Once picked, products such as broccoli and lettuce are "dying", therefore it is important to minimise transport time. This also applies to exotic vegetables such as courgettes. For other products, such as citrus, there is a longer viable shipment window, and therefore slower transport modes become more viable as an alternative. There was no policy of mixing wine with produce however, which were handled as completely separate operations.

A key issue for the shipper, fundamentally influencing the selection of distribution channel, was the degree of critical mass of product. Put simply, if demand levels generally permitted a full vehicle to be shipped from supplier to depot, then, the shipper would manage this in-bound flow itself. If not, it was managed by a third party. For product from Spain, for the most part, there was sufficient volume from each key region to allow the shipper to manage the flows. This was different to the scenarios of supply from other regions of Italy or many other parts of Europe. While the shipper retains the responsibility for setting the rules of and planning the network from Spain to the UK it does, however, outsource the provision of logistics to a logistics service provider to execute the planning it requests. The shipper has just over 1,000 outlets throughout the UK, serviced by a network of about 25 distribution centres located in the main UK distribution regions.

The shipper's supply chain strategy included ambitions to:

- align and integrate its end-to-end supply chain, creating a culture of total supply chain improvement involving all its supply chain partners;
- deliver a reliable and resilient supply chain, continuously improving all the supply chain processes, including international freight transport, to ensure speed, visibility and accuracy in the delivery process.

Fundamentally, availability of product for end-customers was sacrosanct and could not be

jeopardised by any new distribution channel initiative. As well as commercial goals there was a desire to improve on externalities stemming from logistics, notably a focus on environmental emissions performance.

This supply chain strategy had had a bearing on what mode of transport was selected from Spain. As shown in Figure 1, there were many modes of transport that could have been used, but a dedicated road operation with numerous lorries moving product directly from Spain to the UK was the preferred option. Rail trials had proved unsuccessful as there was insufficient volume to fill the trains on the frequency of delivery demanded, and there were concerns around lack of flexibility, especially as the train route clearly had to pass through France where SNCF unions were strong. Short sea shipping alternatives were another possible mode, and great effort was being made by the principal shipping operator to offer more frequent sailings and integrate their operations with inland transport in Spain. However, the distance from the Bilbao, the principal port in Northern Spain, to the main growing regions of Spain, and the criticality of hitting sail departure times to meet promised delivery into depots in the UK meant that it was not a feasible option in the view of the shipper studied.

## **ANALYSIS**

The main findings highlight that although the close management of costs and making progress on the environmental agenda are important what dominates thinking in the industry is reliability of service. Logistics innovations, such as enhancing HC, that do not provide resilience in terms of consistent and reliable delivery mechanisms fail to be entertained as legitimate alternatives. This impacts on the viability of HC initiatives where invariably a certain amount of control is given up compared to the more dedicated options that currently exist.

However, the commercial landscape is shifting and there is an increasing willingness to explore whether the inherent extra uncertainties that exist when this dedicated control is given up can be better managed to give the shipper confidence to shift its position to be more positive towards HC solutions for logistics provision. If flows of product from Spain to the UK were managed in conjunction with other shippers' flows then this could lead to a number of benefits: more frequent more responsive deliveries could be enabled resulting in lower inventory carrying, reduced out of stock wastes and quicker recovery from out of stock scenarios. Environmental benefits could also be secured, such as lower emissions from fuller trailers. Another possibility is to consider combining shipments of product to "cube out" trailers. By combining wine and produce shipments extra consolidation costs could be paid for by ensuring that trailers of trucks were full both in terms of volume and weight (currently there is volume space for wine shipments and weight space for many produce shipments). HC would also allow for greater overall volumes, thus possibly permitting the use of other modes such as rail, or short sea to be used if the other issues of concern could be overcome. This again would have significant environmental benefits.

Fundamentally however, the value metrics that stem from the supply chain strategy of shippers, such as the shipper's strategy covered in our case study, suggest there is a major movement in mind set required for HC initiatives to be entertained for cross Europe shipments such as the

Spain to UK channel. Their targets for excellent availability and low inventory carrying levels dictate that any movement to a more risky solution that lacks the reliability required (and the flexibility to cope when something goes wrong) just is not viable. So HC initiatives must consider their ability to be aligned with the overall supply chain strategy goals of key shippers if they are to be successful. This largely goes beyond what has been researched so far in the area of HC and thus represents a significant finding stemming from this research.

So cost savings on their own are not attractive enough an incentive to move to more enhanced HC in logistics for this sector: there must be a fit with the wider basket of value metrics shippers' demand today from logistics services.

## **CONCLUSION**

The main findings highlight that although the close management of costs and making progress on the environmental agenda are important what dominates thinking in the industry is reliability of service to support availability of product for the end consumer. Logistics solutions that do not provide resilience in terms of consistent and reliable delivery mechanisms fail to be entertained as legitimate alternatives. This impacts on the viability of horizontal coordination where a certain amount of control is given up compared to the more dedicated options that currently exist. However, the commercial landscape is shifting and there is an increasing willingness to explore whether the inherent extra uncertainties that exist when this dedicated control is given up can be better managed to give the shipper confidence to shift its position to be more positive towards horizontal coordination solutions for logistics provision.

A range of questions emerge from the study that provide a direction for future research in this area. Three key ones are identified below:

- What are the types of HC solutions that best fit with the holistic supply chain agenda? - Schmolzi and Wallenburg, (2011) identify 6 scopes of HC which would perhaps be worth exploring in this regard: they are contractual, organisational, functional, service, geographical and resource scopes.
- Who should initiate and manage HC developments? In many ways an independent facilitating logistics company such as a 4PL (see Hingley et al., 2011) would seem to be ideal – however, can a 3PL become a 4PL an act independently or should another entity come in to act as the coordinating brain of the HC initiative
- How should inputs and shares of gain be managed to ensure participating parties are treated fairly (see - Krajewska et al., 2008) so that the HC development is sustainable?

So far, although HC developments in this distribution channel in the sector have been experimented with, especially in trying to use more environmentally friendly modes rather than road, there have been difficulties in successfully integrating them and making them sustainable (durable). The research concludes that what is key is that any HC initiative must be aligned with the overall supply chain strategy of the shipper. Moreover, it is crucial that the HC development must also be perceived to work in the mind-set of the shippers for it to be trialled and possibly eventually established as an on-going way of working.

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# **A SUSTAINABLE ECONOMIC ORDER QUANTITY MODEL WITH CARBON FOOTPRINT**

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## **ABSTRACT**

The paper focus on how the carbon costs modify the classical joint economic lot sizing model of Bannerjee (1986). A number of papers investigate carbon emission of firms in the Economic Order Quantity (EOQ) context. We attempt to classify the most important types of activities leading to carbon emissions, and build them into the model as endogenous factors. We analyze the effects of introducing carbon emission in the model as endogenous variable by employing comparative static analysis. Our results suggest that carbon costs may significantly modify the EOQ ordering policy. In literature there are a limited number of contributions to combine carbon costs vulnerability with logistics and Supply Chain Management (SCM) costs.

## **1. INTRODUCTION**

The paper focus on how the carbon costs modify the classical joint economic lot sizing model of Bannerjee (1986). This model investigates supplier-buyer relationship in a supply chain context. A number of papers investigate carbon emission of firms in the EOQ context. These papers introduce transportation costs (Bonney, Jaber (2011), Wahab et al. (2011)), restrictions (Hua et al. (2011)), or price discount-type limitations (Bouchery et al. (2012)) in the model in order to identify carbon sensitive costs.

Our paper contributes to the research line followed by the above mentioned previous works. We attempt to classify the most important types of activities leading to carbon emissions, and build them into the model as endogenous factors. We analyze the effects of introducing carbon emission in the model as endogenous variable by employing comparative static analysis.

The paper will present an EOQ type optimization model involving carbon costs.

Our results suggest that carbon costs may significantly modify the EOQ ordering policy. We provide estimations on the difference in EOQ with and without built in carbon costs.

Introduction of carbon costs into the EOQ type optimization model will result in lower emission, but higher supply chain costs.

The paper provides an abstract picture of real business practices. As mathematical modeling generally, it allows the investigation of limited number of factors.

In literature there are a limited number of contributions to combine carbon costs vulnerability with logistics and SCM costs.

## **2. THE BASIC MODEL**

Parameters of the model:

-  $D$  demand of the buyer per time unit,

- $P$  production rate of the supplier,
- $s_b$  setup cost of an ordering of the buyer,
- $h_b$  holding costs of the products of the buyer,
- $s_v$  setup cost of an ordering of the supplier,
- $h_v$  holding costs of the products of the supplier,
- $t^c$  length of a cycle.

Decision variable of the model

- $q_b$  lot size (order level) of the buyer,
- $q_v$  lot size (production level) of the supplier,
- $q$  joint lot size (order level) of the system.

The material flow of the model is shown in figure 1.

### Figure 1 Material flow of the model

In the model we use the traditional assumption of the economic order quantity model (Banerjee (1986)). The costs of the supplier and buyer consist of setup cost and holding cost of used and new products. The inventory levels of the buyer and the supplier of the supply chain are shown in figure 2. and 3.

### Figure 2 Inventory levels of the buyer

### Figure 3 Inventory levels of the supplier

The cost function of the buyer is

$$TC_b(q_b) = s_b \cdot \frac{D}{q_b} + \frac{q_b}{2} \cdot h_b.$$

The cost function of the supplier is the following in dependence of cost parameters

$$TC_v(q_v) = s_v \cdot \frac{D}{q_v} + \frac{q_v}{2} \cdot h_v.$$

### 3. The optimal lot sizes and collection rates of the partial models

Banerjee (1986) has investigated the development of the costs for both participants of the

supply chain. His conclusion is that the total system costs can be reduced with cooperation. However, he did not discuss how to divide the cost savings. Sucky (2006) has offered a bargaining model which gives a solution to this problem. Our model is an extension of model of Banerjee (1986) with reverse logistics. We summarize the partial and system wide solution of the extended model.

### 3.1. Optimal decision of the buyer

The buyer's problem is a simple EOQ model. The optimal solution for the lot size is

$$q_b^o = \sqrt{\frac{2 \cdot s_b \cdot D}{h_b}},$$

and the optimal costs

$$TC_b(q_b^o) = \sqrt{2 \cdot D \cdot s_b \cdot h_b}.$$

In the next subsection we solve the problem of the supplier without coordinated lot size.

### 3.2. Optimal lot size and collection rate of the supplier

As shown before the solution of the supplier's problem depends on the sequence of the manufacturing and remanufacturing activities.

$$q_v^o = \sqrt{\frac{2 \cdot D \cdot s_v}{h_v}}$$

and the cost function

$$TC_v(q_v^o) = \sqrt{2 \cdot D \cdot s_v \cdot h_v}$$

In the next section we introduce the carbon emission limit.

## 4. Carbon constraints of the participants

Let us assume that the carbon emissions of ordering and inventory holding are known. The parameters are the following (Hua et al (2011), Chen et al (2013)):

- $e_b$  the amount of carbon emission in executing an ordering of the buyer,
- $g_b$  the amount of carbon emission in holding of the products of the buyer,

- $C_b$  carbon cap of the buyer,
- $e_v$  the amount of carbon emission in executing an ordering of the supplier,
- $g_v$  the amount of carbon emission in holding of the products of the supplier,
- $C_v$  carbon cap of the supplier.

The carbon constraints for the buyer are

$$e_b \cdot \frac{D}{q_b} + \frac{q_b}{2} \cdot g_b \leq C_b,$$

and for the supplier

$$e_v \cdot \frac{D}{q_v} + \frac{q_v}{2} \cdot g_v \leq C_v.$$

These two last constraints can be written as

$$\underline{q}_b \leq q_b \leq \bar{q}_b,$$

and

$$\underline{q}_v \leq q_v \leq \bar{q}_v,$$

if the inequalities can be solved for some positive lot sizes.

## 5. The joint economic lot size models with carbon constraints

The joint economic lot size with carbon constraints is with cost function of the buyer

$$TC_b(q) = s_b \cdot \frac{D}{q} + \frac{q}{2} \cdot h_b,$$

and the cost function of the supplier is the following in dependence of cost parameters

$$TC_v(q) = s_v \cdot \frac{D}{q} + \frac{q}{2} \cdot h_v$$

such that

$$\max\{\underline{q}_b, \underline{q}_v\} \leq q \leq \min\{\bar{q}_b, \bar{q}_v\}.$$

The last equations are the carbon constraints for a possible joint economic lot size. If the set of possible joint lot sizes are empty, i.e.

$$\min\{\bar{q}_b, \bar{q}_v\} < \max\{\underline{q}_b, \underline{q}_v\},$$

then there exists no solution for the carbon constrained joint economic lot size model.

Let us now analyze the joint economic lot size model with joint cost function

$$TC_b(q) = (s_b + s_v) \cdot \frac{D}{q} + \frac{q}{2} \cdot (h_b + h_v).$$

The joint economic lot size under carbon constraints is

$$q^o = \begin{cases} \max\{\underline{q}_b, \underline{q}_v\} & \sqrt{\frac{2 \cdot D \cdot (s_b + s_v)}{h_b + h_v}} \leq \max\{\underline{q}_b, \underline{q}_v\} \\ \sqrt{\frac{2 \cdot D \cdot (s_b + s_v)}{h_b + h_v}} & \max\{\underline{q}_b, \underline{q}_v\} \leq \sqrt{\frac{2 \cdot D \cdot (s_b + s_v)}{h_b + h_v}} \leq \min\{\bar{q}_b, \bar{q}_v\} \\ \min\{\bar{q}_b, \bar{q}_v\} & \min\{\bar{q}_b, \bar{q}_v\} \leq \sqrt{\frac{2 \cdot D \cdot (s_b + s_v)}{h_b + h_v}} \end{cases}$$

The optimal costs are

$$TC_b(q^o) = (s_b + s_v) \cdot \frac{D}{q^o} + \frac{q^o}{2} \cdot (h_b + h_v).$$

## 6. Conclusions and further research

In this paper we have investigated the Economic Order Quantity model with carbon constraints. We have given a necessary condition for existence of an optimal solution of the model. We have shown that the system-wide optimal joint economic lot size is influenced by the carbon caps of the participants of the supply chain.

In a next analysis we can investigate an emission trading between the buyer and supplier. If it is allowed to purchase pollution rights, then the supply chain is an open system with market connection. These cases can be modeled with game theoretical models and methods.

## ACKNOWLEDGMENTS

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# **DYNAMIC FORECASTING WITH DYADIC HARMONIC ANALYSIS IN SUPPLY CHAINS: A REVIEW**

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## **Introduction**

As global and local business competition is getting more intensive, companies face a growing need to forecast their future demand as accurately as possible. Precise forecasting helps not only in satisfying customer demand but also in reducing costs by mitigating unnecessary stocks.

Recognizing this need, many researchers elaborated many types of predictive models for time series. There are simple approaches which contain a lot of pre-conditions (e.g. stationarity) but are very easy to apply (e.g. regression calculation, moving average, etc.). There are more complicated methods which are more general and might be applied for more realistic business cases – that are not that simple than theoretical time series – but are rather difficult to apply, because of the relatively big number of calculations (e.g. ARIMA, SARIMA, Box-Jenkins).

A common problem in time series analysis is the model selection itself. Before using a model for prediction the decision maker has to be aware of the possible group of applicable models. Other usual difficulty is the computational time or the rather slow forecasting process. In some cases the interpretation of the gained results is also a crucial part. Besides – above all possibly- the accuracy of the prediction is also an important issue.

In this paper we will present the Walsh-Fourier transforms and its connection to time series analysis. The paper surveys the existing statistical literature to make effective forecasting with dyadic harmonic analysis. We will point out that this mathematical discipline i.e. dyadic analysis makes it possible to fulfill fast calculation in forecasting process.

The approach is based upon literature reviews. The most important economic and business application of dyadic analysis is summarized. The summary enables to focus the analysis on new fields of time series analysis. Based on the existing research findings, it can be stated that dyadic harmonic analysis and Walsh-Fourier transforms are usable techniques to construct forecasting for supply chain demand.

Although in the literature there are only a few contributions to handle time series problems with Walsh-Fourier transform, we have collected all relevant economic and business applications of dyadic harmonic analysis.

This paper offers a relatively new time series method with which the calculation time of

forecasting can be reduced significantly.

### **Literature review**

To real-time stationary processes, firstly Kohn (1980) introduced the statistical application of Walsh-Fourier functions. Before that it was well known among economic experts that all processes could be decomposed by trigonometric functions (Cryer, 1986, etc.). Kohn showed that all of these trigonometric functions have their Walsh functions analogs (that means that they can be described by  $-1, +1$ ), so a real-time stationary time-series can be decomposed to Walsh functions. Since Kohn, many other articles emerged in the statistical literature, mainly in the '80-ies and in the early '90-s e.g. Morettin (1981, 1983) and Stoffer (1985, 1987, 1990, 1991).

In his paper, Stoffer (1991) laid down the basics of frequency and sequency domain analysis by describing the Walsh-ordered Hadamard-matrix (which is symmetric and includes only  $-1$  and  $+1$ ). And as an analogue to Fourier transform, introduced the Walsh periodogram, which made it possible to transform the original data similarly as cosine, sine trigonometric transforms. Stoffer also examined different statistical applications of Walsh-Fourier functions, analyzed the variance and coherence of Walsh-Fourier analysis.

Nason et al (1998) applied non-decimated wavelet representations for the statistical modeling of time-series. The wavelet representations were used as variables in a statistical model to provide predictions of another time series. The authors highlighted which components in the explanatory time series drive the forecasted time series, thus a reliable prediction could be gained. They emphasized that the wavelet transforms (which are based on Walsh-Fourier transforms) provide a very rapid and accurate computational process.

There are more recent papers which are dealing with dyadic analysis, e.g. Bichescu et al (2009). The authors created a Walsh-Fourier model for recurrent subcontracting of balancing the workload of firms. They used the characteristic of  $-1, +1$  for insourced production ( $-1$ ) and outsourced production ( $+1$ ) in terms of the desired capacity utilization. If we consider two axes; demand as vertical and time as horizontal; and establish a curve of demand profile, in case the demand is higher than the current demand the specific firm outsources the production in order to maintain the desired capacity utilization. In case it is below the desired capacity line, the firm insources the production. This is a typical Walsh-Fourier problem and the dyadic analysis is very well applicable in these situations. The authors also examined optimal inventory control under these circumstances by a modified Walsh-model. This paper sheds light on the possible application of Walsh-Fourier analysis in examining the cooperation of supply chain participants e.g. balancing their inventory level by dyadic harmonic analysis.

### **Research results - About the Walsh-Fourier forecasting**

By the start of the twentieth century, scientists were well aware of the existence of many useful orthogonal systems of continuous functions, such as the set of orthogonal trigonometric functions that occur in Fourier analysis. The field was developed further as mathematicians constructed orthogonal systems with functions that were not continuous. In 1923, J. L. Walsh



published a complete set of orthogonal functions that take on only two values, + 1 ("on" and "off"), and are similar in oscillation and many other properties to the trigonometric functions. Although other binary-valued, sets of discontinuous orthogonal functions were constructed (Haar and Rademacher), the system due to Walsh is more prominent in terms of recent studies and applications. Paley reintroduced Walsh functions to the scientific community by defining them as the product of Rademacher functions. Walsh's definition, in terms analogous to the behavior of trigonometric functions, is more appealing in applications, nevertheless, Paley's definition was better suited for mathematical consideration. (Stoffer, 1991)

The Walsh-Fourier forecasting is based on the Fourier analysis. The [infinite sum](#)

$$f(t) = a_0 + \sum_{n=1}^{\infty} (a_n \cdot \sin(nt) + b_n \cdot \cos(nt))$$

is called the Fourier series of  $f$ . For a periodic function  $f(t)$  that is integrable on  $[-\pi, \pi]$ , the numbers

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(t) \cos(nt) dt, \quad n \geq 0$$

$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(t) \sin(nt) dt, \quad n \geq 1$$

are called the Fourier coefficients of  $f$ . One introduces the partial sums of the Fourier series for  $f$ , often denoted by

$$f_N(t) = a_0 + \sum_{n=1}^N (a_n \cdot \sin(nt) + b_n \cdot \cos(nt)), \quad N \geq 0$$

The partial sums for  $f$  are [trigonometric polynomials](#). One expects that the functions  $f_N$  approximate the function  $f$ , and that the approximation improves as  $N \rightarrow \infty$ .

The same basic ideas are employed in Walsh-Fourier analysis. The Walsh functions are similar in some respects to the system of sines and cosines used in Fourier analysis, however, unlike their sinusoidal counterparts, the Walsh functions are square waveforms that take on only two values, + 1 and -1 ("on" and "off"). The sinusoids in Fourier analysis are distinguished by their frequency of oscillation  $n$  in terms of the number of complete cycles they make in the interval  $0 \leq \lambda < 1$ .

Let  $X(0), X(1), \dots, X(N - 1)$  represents time series data. We propose that a time series is the superposition of Walsh functions at various sequencies,

$$X(\tau) = \sum_{n=1}^q A_n \cdot wal_n(\tau), \quad \tau = 0, 1, \dots, N - 1$$

where functions  $wal_n(\tau)$  are Walsh functions.

We will be interested in the discrete version of the Walsh functions since time series typically are sampled at discrete, equidistant time points. The first eight discrete, sequency-ordered Walsh

functions,  $wal_n(\tau)$  ( $n = 0, 1, \dots, 7$ ), corresponding to a sample of length  $N = 2^3$  are shown below as the rows (columns) of a symmetric matrix called the Walsh-ordered Hadamard matrix,  $H_w(3)$ :

$$H_w(3) = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & -1 & 1 & -1 \end{bmatrix}$$

Figure 1 shows the first eight of these functions.

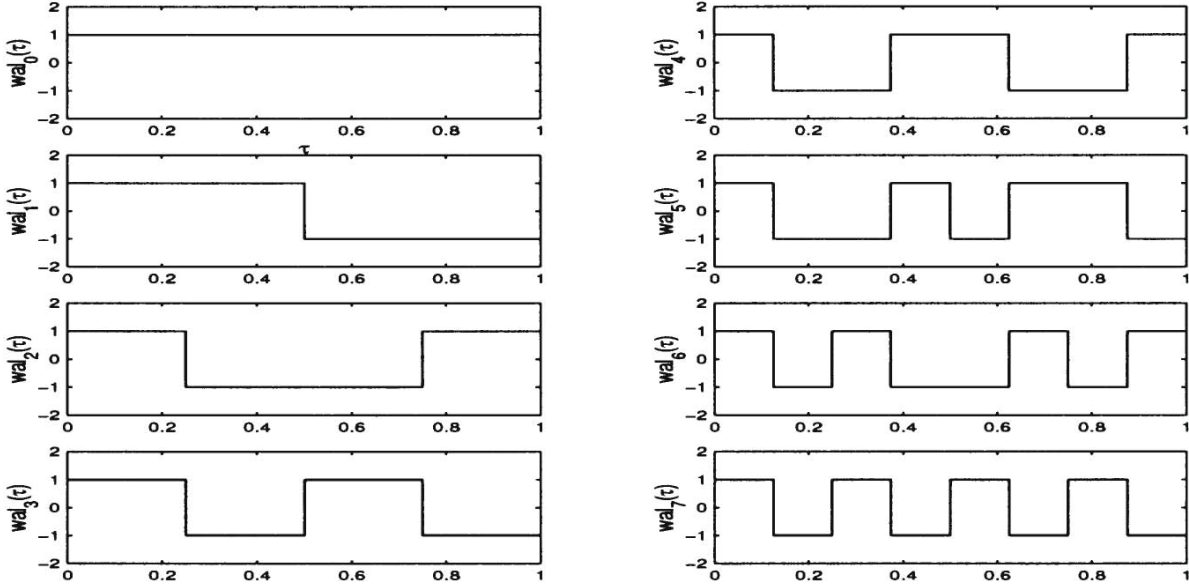


Figure 1. The first eight Walsh functions

The best fitting model is looking for in business forecasting. In this case first the best parameters must be determined. The parameters are calculated solving the next linear equation system for parameters  $A$

$$X = H_w(p) \cdot A$$

where  $X = [X(0), X(1), \dots, X(N-1)]$ ,  $A = [A_1, A_2, \dots, A_{2^p}]$ . The problem in this linear equation system is that  $N \neq 2^p$ . If the sample length  $N$  is not a power of 2, dummy observations equal to

the sample mean may be appended to the series in order to make the new sample length a power of 2. Similarly, observations may be deleted to obtain a new sample length that is a power of 2. Provided that not too many observations are appended or deleted, the transform will not be noticeably different than that of the original data, although the sequences will be slightly different sample length a power of 2.

The new forecast now is

$$\begin{bmatrix} X \\ \tilde{X} \end{bmatrix} = \begin{bmatrix} H_w(p+1)_1 \\ H_w(p+1)_2 \end{bmatrix} \cdot A ,$$

where vector  $\tilde{X}$  is the forecasted demand, and matrices  $H_w(p+1)_1$  and  $H_w(p+1)_2$  are the first  $2^p$  columns of Walsh-ordered Hadamard matrix  $H_w(p+1)$ .

### Conclusion

In the literature there are only a few contributions to handle time series problems with Walsh-Fourier transform. We have collected all relevant economic and business applications of dyadic harmonic analysis.

In real business practice the offered statistical method seems to be very complicated, but the gained new information can overcome the methodological discomfort.

This paper offers a relatively new time series method with which the calculation time can be reduced significantly.

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## Section 2 – Resilience in Supply Chains

### INTERPRETATIONS OF THE VALUE CONCEPT IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT: A CONTENT ANALYSIS

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#### 1. INTRODUCTION

In last year's conference we presented the inaugural paper in a programme of research that sought to explore the conception, communication and implementation of what is perhaps the most fundamental concept within contemporary logistics and supply chain management (and even indeed within business and management most generally); the concept of 'value' (Fisher *et al.*, 2012). In that discussion paper we characterised the origins of the notion of value within Philosophy, Sociology and Economics before then turning to the General Management literature. We suggested that Porter's (1985) *Value Chain Analysis (VCA)* was the most widely conveyed and influential invocation of the concept of value within this literature, and applied VCA as a framework for organising that subsequent stage of study. We used two units of analysis (UOA) to explore how value was conceived and defined within the primary value adding disciplines (activities) defined in Porter's VCA model: Procurement, Logistics, Operations Management and Marketing & Sales. The first UOA was the official dictionaries of the UK professional bodies that represent these discipline areas. The second was the key textbooks used generally within the Marketing, Procurement, Operations Management and Logistics disciplines to educate undergraduate, postgraduate and continuing professional development students. That initial stage of study led us to conclude that the concept of 'value' seemed to lack consistent definition between or even within these disciplines, and seemed to mean very different things to different people. Since that initial study was reported at ISL'12 the authors have expanded coverage of both the official dictionaries and text books that formed the two UOAs; particularly within Purchasing and Logistics/ Supply Chain Management (SCM).

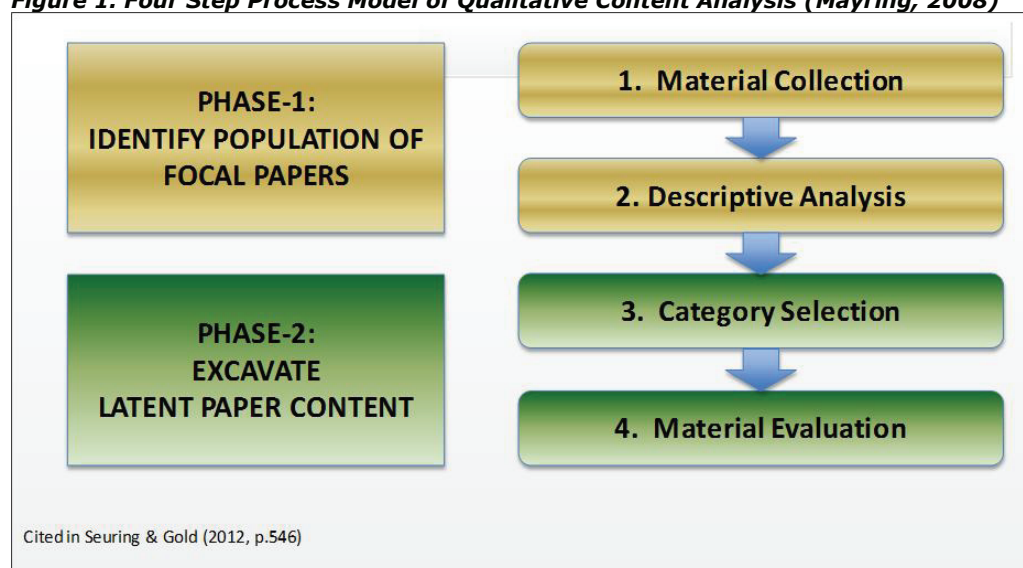
This paper represents the second stage of that programme of research. It presents the initial findings of a comprehensive content analysis of peer-reviewed articles on the topic of 'value' within Purchasing, Logistics and SCM journals that was promised as the future research in last year's paper (*op cit.*). The analysis of these journal articles therefore constitute a third UOA and are intended to triangulate the findings from the first two. The purpose remains the same: to help raise awareness of academic, methodological and practical issues caused by this key definitional dilemma; and to establish whether it is possible to identify a common denominator or 'essence' of the value concept that improves its utility to academics and practitioners working within all parts of the supply chain.

#### 2. CONTENT ANALYSIS

The method adopted to undertake this study was Content Analysis (CA). This is an established bibliographic research method that is defined by Berelson (1952, p.55) as "... any methodological measurement applied to text (or other symbolic materials) for social science purposes." and by Mayring (2008) as "... systematic, rule-governed, and theory-driven analysis of fixed communication". Whilst not prevalent within SCM research this method does have lineage within the field, as aptly summarised by Seuring & Gold (2012). They authors suggest that CA typically entails two broad phases of study. Phase-1 ultimately identifies the individual articles that are subsequently to form the focus of detailed analysis from the wider population of existing articles. Phase-2 then 'excavates the latent content' of these articles; typically using some form of thematic analysis to interpret the underlying meaning and obtain insight (see for example Avery *et al.*, 2012). Seuring & Gold (*op cit.*) stress the importance of following a clear and purposeful process structure, and highlight Mayring's (2008) four-step process model for conducting

qualitative content analysis. As indicated in Figure 1 the first two steps of this process model relate to the first phase summarised above (identify the population of focal articles), whilst the third and fourth step relate to the second phase (excavate latent article content).

**Figure 1. Four Step Process Model of Qualitative Content Analysis (Mayring, 2008)**

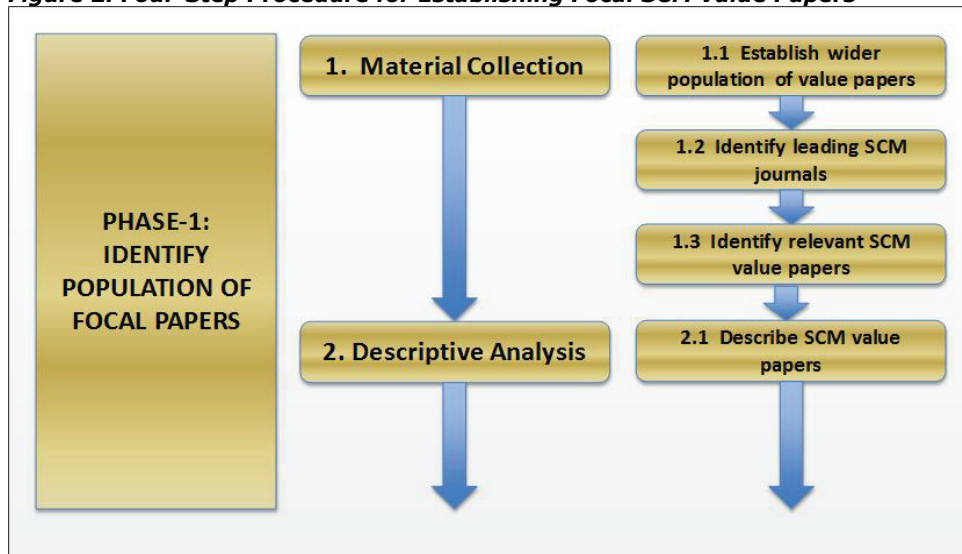


The first step in Mayring’s model is *Material Collection*, during which the UOA is identified (usually, although not exclusively, peer-reviewed journal articles). This stage also entails a search across one or more bibliographic databases using a key word (KW) search strategy. Seuring & Gold point out that for reasons of pragmatism, the researcher will usually need to make an informed choice to condense the population of target articles to a manageable number, and that this choice needs to be justified in relation to the research objective. This typically involves being selective in the range and/or timespan of journals searched. Step 2 is *Descriptive Analysis*, during which the formal characteristics of the material are assessed to provide background information for the subsequent steps. This includes useful information about the distribution of articles across the various journals. The authors (*op cit.*) also note that additional processing might be required at this point to ensure that the identified articles really deal with the topic of analysis, and this might entail reading each article to reflect upon their respective appropriateness. The population of focal articles marks the start of Step 3, *Category Selection*. This entails selecting the structural dimensions and analytical categories that are to be applied to the identified material. The last step is then *Material Evaluation*, during which the identified articles are analysed according to the dimensions established above in order to establish the requisite insight.

### 3. METHOD

The method developed and applied by the authors for the study reported upon in this paper was based upon the model discussed above. This new method entailed the four procedural steps that are illustrated in Figure 2; each of which is cross-referenced against the CA process model suggested by Seuring & Gold (2012). This figure clearly shows that the scope of the material presented in this paper equates to Phase-1 of this CA project; the identification of the set of *focal* peer-reviewed journal papers that address the general conception of ‘value’ within the fields of Purchasing, Logistics or SCM that are subsequently to be analysed in detail during Phase-2. At the time of writing this paper, Phase-2 was work in progress and it is hoped that this will be complete by the date of the Symposium in Vienna so that the findings might be included in the presentation of this paper. The following sections discuss each of these procedural steps in turn.

**Figure 2. Four-Step Procedure for Establishing Focal SCM Value Papers**



## 4. DISCUSSION

### 4.1 Establish the wider population of value papers

The first procedural step involved establishing the wider population of journal papers that address the concept of 'value'. It was decided to conduct the subsequent search across the two largest and most widely used bibliographic databases that encompass Business and Management. The first of these was Business Source Premier (BSP), which claims to be the largest and most popular business research database. BSP covers all business disciplines and at the time of the study encompassed over 2,300 journals of all types; 1,100 of which are peer-reviewed. BSP offers full text back to 1886 and searchable cited references back to 1998. The second database was Emerald Management Xtra (EMX), which claims to be the largest and most comprehensive collection of peer-reviewed management journals, featuring over 120 full text journals. It should be noted that some journals are duplicated; appearing on both databases.

In order to identify those journal papers that specifically address the general nature and conception of 'value', the team speculated that the word would appear in both the title and key words of that paper. Table 1 summarises the findings of the resultant key word searches across both BSP and EMX. Neither set of searches had any date range limitation. In the case of BSP, the first figure in each cell represents the number of "hits" when the publication type was restricted to 'Academic Journals' in the advanced search feature. The figure in brackets is the number of hits when this is further limited to 'Scholarly (peer reviewed) journals'. The results clearly indicate that a large body of papers seem to have addressed the concept of value within the business and management journals.

**Table 1. Prevalence of 'value' papers within management journals**

"VALUE" IN ...	TOTAL NUMBER OF "HITS"	
	BUSINESS SOURCE PREMIER (BSP)	EMERALD MANAGEMENT XTRA (EMX)
Title (TI)/ Article Title	23,053 (23,003)	2,256
Key word (KW)/ Key word	9,570 (9,562)	1,728
Title AND Key word	3,839 (3,838)	766

### 4.2 Identify leading SCM journals

Having established the wider set of peer-reviewed value papers, the next step was to establish the filter that would derive the sub-set of these papers that were pertinent to our target field of Purchasing, Logistics and SCM (referred to by the collective noun 'SCM' from this point onward within this paper). In accord with Seuring & Gold (2012), such an

exercise involves issues of pragmatism to ensure that the resultant papers are reduced to a manageable number. To facilitate an informed choice in this matter, the researchers decided to first ensure that the resultant key word search would encompass all of the 'leading' journals within the SCM field. As a vehicle for this exercise they consulted ABS (2010) and considered all of the SCM journals that were listed under the subject code of 'Operations, Technology and Management' (OPS&TECH). They represented just seven of the 40 journals listed under this code (see p.32). From these, all with a quality ranking of 2-4\* were selected as the 'leading' SCM journals (six of the seven journals). The resultant list is detailed in Table 2. In addition to the journal title and acronym, each table entry also notes its publisher, whether it is included within the BSP and EMX bibliographic databases, and that journal's quality ranking within both the 2010 and 2009 editions of the ABS journal quality ranking list.

**Table 2. Leading SCM journals for bibliographic key word search**

No.	Journal Name	Acronym	Publisher	BSP	EMX	ABS (2010)	ABS (2009)
1.	<i>Supply Chain Management: An International Journal</i>	SCMIJ	Emerald	✓	✓	3	3
2.	<i>International Journal of Logistics: Research &amp; Applications</i>	IJLRA	Taylor & Francis	✓	✗	2	2
3.	<i>International Journal of Logistics Management</i>	IJLM	Emerald	✓	✓	2	2
4.	<i>International Journal of Physical Distribution and Logistics Management</i>	IJPDLM	Emerald	✓	✓	2	1
5.	<i>(European) Journal of Purchasing &amp; Supply Management</i>	JP&SM	Wiley	✓	✗	2	2
6.	<i>Journal of Business Logistics</i>	JBL	Elsevier	✓	✗	2	2
7.	<i>Journal of Supply Chain Management</i>	JSCM	Wiley	✗	✗	1	1

### 4.3 Identify relevant SCM value papers

Reference to the above table reveals that all six of the leading SCM journals contain the words 'logistics', 'supply chain management' or 'purchasing' within their titles. Equipped with this information it was possible to construct a series of key word searches across each of the BSP and EMX databases respectively in order to distil a pool of relevant SCM value papers. These searches were again premised upon the assumption that relevant papers would contain the word 'value' in both the article title and author supplied key words. The results are illustrated in Table 3, with each of the six constituent searches being identified by a unique search reference code (S1-S6). It should be emphasised that these searches did not restrict themselves ONLY to the six leading SCM journals identified in the previous section. All journals that contained *any* of the three words above within their title were encompassed by this procedure.

The results are interesting. Turning first to the three key word searches within BSP (S1-S3) and it is apparent that all of the hits (27) are from the leading SCM journals identified in the previous procedural step. This would seem to validate the search strategy adopted by the authors above. Of these, IJPDLM yielded by far the greatest number of relevant SCM value papers (16). This was followed by IJLRA and SCMIJ (with four papers each). There were no hits from a journal with 'Purchasing' in the title. This included JP&SM, which had previously been identified as one of the six leading SCM journals.

The three subsequent searches within EMX (S4-S6) were also revealing. Even though BSP contains significantly more journal publications in total than EMX, and also contains more of the leading SCM journals (see Table 2), the EMX searches yielded a higher number of hits in total. They also yielded a higher number of hits for all three of the leading SCM journals that it had in common with BSP, which suggests that its chronological coverage of



these journals is more extensive than its BSP counterpart. Again, these three 'shared journals' revealed themselves as the major sources of relevant SCM value papers. IJPDLM is clearly the leading source (22 relevant papers), with SCMIJ emerging as the second (13 papers) and IJLM the third (9 papers) most productive. Searches S4-S5 again reinforced the earlier conclusion regarding the apparent validity of the key word search strategy, with 45/51 hits being derived from the leading SCM journals. Interestingly, five of the six hits from non-leading journals revealed by S4 were from *Logistics Information Management* (LIM). This journal is listed within ABS (2010) under 'INFORMATION MANAGEMENT' and with a quality ranking of only '1'. Lastly, and in common with the search of BSP, no hits were registered for any purchasing journal. It would therefore seem fair to conclude that the Purchasing journals do not have much to say about the conception of 'value'.

**Table 3. Identifying relevant SCM value papers**

BSP		EMX	
Ref.	Search Criteria	Ref.	Criteria
S1	<p><b>['logistics' in SO=publication name] AND ['value' in TI=Title] AND ['value' in KW=author supplied key words]</b>            ... returns 23 hits</p> <p>Source of these hits (23/23 from LEADING SCM JOURNALS):</p> <p>IJLRA = 4, IJLM = 3, IJPDLM = 14, JBL = 2</p>	S4	<p><b>['logistics' in Volume Title] AND ['value' in Article Title] AND ['value' in Key words]</b>            ... returns 38 hits</p> <p>Source of these hits (32/38 from LEADING SCM JOURNALS):</p> <p>IJLM = 9, IJPDLM = 23            Other (non Leading) = 6</p>
S2	<p><b>['supply chain management' in SO=publication name] AND ['value' in TI=Title] AND ['value' in KW=author supplied key words]</b>            ... returns 4 hits</p> <p>Source of these hits (4/4 from LEADING SCM JOURNALS):</p> <p>SCMIJ = 4</p>	S5	<p><b>['supply chain management' in Volume Title] AND ['value' in Article Title] AND ['value' in Key words]</b>            ... returns 13 hits</p> <p>Source of these hits (13/13 from LEADING SCM JOURNALS):</p> <p>SCMIJ = 13</p>
S3	<p><b>['purchasing' in SO=publication name] AND ['value' in TI=Title] AND ['value' in KW=author supplied key words]</b>            ... returns 0 hits</p> <p>JP&amp;SM = 0</p>	S6	<p><b>['purchasing' in Volume Title] AND ['value' in Article Title] AND ['value' in Key words]</b>            ... returns 0 hits</p> <p>JP&amp;SM = 0</p>

#### 4.4 Describe relevant SCM value papers

Whilst the previous step provided insight into the distribution of the relevant SCM value papers across journals, this fourth procedural step specifically sought to enhance such descriptive analysis and also to ultimately yield the subset of focal SCM value papers that will form the raw material for the detailed article content excavation during Phase-2 of this CA study (see Figure 1). This fourth step involved producing and analysing three constructs from the data yielded by the key word searches S1-S6. The first of these was a distribution by year of publication of the papers for each of the six searches. Space constraints prohibit the inclusion here of an illustration of this frequency distribution, although this will be included in the conference presentation. However, this chronological analysis confirmed that coverage of journals within BSP started later than their EMX counterparts: The earliest paper yielded by search S1 ('logistics') was 2004, whilst its EMX counterpart search (S4) yielded papers as far back as 1989. Likewise, the earliest paper yielded by BSP search for 'supply chain management' (S2) was 2009 in contrast to its direct EMX equivalent (S5) that yielded papers in SCMIJ as far back as 1999. This analysis also revealed a second interesting finding: there seemed to be a notable surge in publication of relevant SCM value papers approximately every four years (1999-2000, 2003-4, 2008-9, 2011-12). This would suggest a cyclical interest in this subject matter.

The second construct was a table listing the various specific invocations (objects) of value within the peer reviewed papers that were identified by the key word searches (see Table 4). This table was produced using a subjective, two-part parsing exercise. First, the abstracts of all of the papers yielded by these searches were read to distil their primary focus or specific invocation of the value concept (reason or context for the word 'value' appearing in the paper's title and key words). Second, the resultant invocations were organised to facilitate comparison between those derived from the BSP and EMX searches respectively. This sometimes necessitated the clustering of value invocations into thematic areas. For example, the key word searches across both databases yielded notable clusters of journal papers that focused as their subject matter on different attributes of the 'Value Stream' and 'Value Chain' concepts. However, when subsequently read these were found to contain no definition nor discussion of the general concept of 'value' par se. The most important observation here is the sheer number and diversity of value invocations contained within this table.

**Table 4. "Invocations" of value within SCM value papers**

<b>BSP (Searches: S1, S2)</b>	<b>EMX (Searches: S4, S5)</b>
VALUE STREAM: - Mapping - Analysis - Management	Logistics value/ of
VALUE CHAIN: - Analysis - Flexibility - Framework (and method) - Branding - Manufacturing technology - Sustainability	VALUE CHAIN: - Analysis - Flexibility - Framework (and method) - Branding - Manufacturing technology - Sustainability - Management - Improvement - Virtual - And integrated materials management - In schooling!
Value added services (for SMEs)	VALUE ADDED: - Strategies - System - Through logistics - Services (for SMEs; US electrical components distribution)
Best value (supply chain)	Best value (supply chain)
Product residual value	Product residual value
Customer value	Customer value
Value of a 4PL provider	Value of a 4PL provider
Value measurement (in VALUE CHAINS)	Value measurement (in VALUE CHAINS)
Value networks	Value networks
Value of information	Value of information
Value recovery	Value recovery (network design)
Value catalyst	Value catalyst
Value management (in collaborative networks)	Value management (in collaborative networks)
Value delivery (process)	Value delivery (process)
Shareholder value	Shareholder value
Maritime logistics value	Value creation: - Via partnerships - Via supply chain relationships - Via e-business
Relevant value	Net Present Value (NPV)
	Economic Value Added
	Value challenges
	IS business value
	Value improvement
	Value re-engineering
	Value hierarchy (model)
	Perceived value

The third and final construct was also a product of the two-part parsing exercise summarised above. This construct was a list of those SCM value papers that were deemed

to substantively discuss a general conception of value rather than a specific invocation of 'value' as per the above. These focal SCM value papers were: (Willersdorf, 1990; Fawcett & Fawcett, 1995; Cox, 1999; Poon & Lau, 2000; Bititici *et al.*, 2004; Rainbird, 2004a; 2004b; Turner *et al.*, 2004; Barber, 2008 and Bourlakis *et al.*, 2012). Eight of these ten papers were from the leading SCM journals identified during step two of the procedure. All eight were from the top three yielding journals that were previously highlighted in section 4.3. Six were from IJPDLM and one each from SCMIJ and IJLM. Surprisingly, two of the ten focal papers were *not* from any of the leading SCM journals, and both of these were instead from LIM. As a final important observation, *none* of these focal papers took the form of a comprehensive literature review or meta-analysis of the subject of 'value' or its evolution within the SCM literature.

## 5. CONCLUSIONS, IMPLICATIONS & FUTURE RESEARCH

This paper describes Phase-1 of the second stage of a major programme of research to explore and understand the conception of 'value' within the SCM field. It details a new CA method and provides valuable insights and directions for future research. Whilst the value concept is the cornerstone of the contemporary supply chain concept (Fisher *et al.*, 2012), this Phase-1 study of peer-reviewed SCM journals has triangulated the conclusions from the previous stage of this wider programme of work that was premised upon an analysis of key text books and official dictionaries of the professional bodies of the supply chain functions within the UK (*op cit.*); **that there is currently no coherent conception of value within the SCM literature.** This claim is evidenced by the sheer diversity of invocations of value summarised in Table 4 and the fact that we were unable to identify a single literature review or meta-analysis on the subject 'value' within the SCM journals.

This conclusion has significant implications for practitioners in the SCM field. For example, how can you reward employees for their contribution to maximising customer value and hence organisational performance if you don't know what value is? How can you design and effective or efficient supply chain based upon the value principle if none of the partners have a common understanding –let alone consensus- of what value amounts to? To what extent might this explain sub-optimal supply chain implementation projects, and the failure of initiatives such as Lean and Agile to live up to their promises? This conclusion has no less significant implications for academics and researchers in our field. Probably the most significant implication is that this raises the question of how is it possible to study something that you can't define? It consequently also throws into question a significant proportion of the extant research within SCM, and might also necessitate researchers in the future adopting research strategies that are currently alien or marginalised in the conferences and journals within our field.

This situation has given the authors pause for thought: What can be the *essence* that is common to all the invocations of value that we identified during this study? Indeed, *is* there an essence: is it really possible that a single, coherent conception of value can apply to all these invocations and provide an effective 'guiding light' for our field? Should we think the unthinkable: is 'value' an empty concept that is nothing more than a flaccid and 'valueless' adjective that should be dropped from the management vocabulary and perhaps replaced by the word 'money', 'cash' or 'profit' ... or even '[work] flow'?

We are not in a position to answer this yet. However we hope that our planned future programme of work will cast further light on this profound issue. Our immediate future research will first ensure comprehensive methodological coverage by extending the Phase-1 CA protocol to the leading Operations Management journals to expand the pool of focal papers. Once complete, Phase-2 of the CA study will be implemented to undertake the detailed analysis of the latent content of these papers. It is then planned to undertake a similar CA study of the contemporary operations and management paradigms (COMPs) that have come to underpin and define our conception of the supply chain. This will start with the Lean and Agile paradigms as these are arguably the most influential. However, it is hoped to then extend this to other paradigms such as Six Sigma and the Theory of Constraints.

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# **ORGANIZATIONAL RESILIENCE OF SWEDISH TEXTILE ENTERPRISES THROUGH CRISIS STRATEGIC PLANNING - A RESEARCH REVIEW**

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## **INTRODUCTION**

Resilience, in an organizational sense means the ability to survive and thrive in crises and turbulences (Vargo & Seville, 2011). It is associated with established activities like crisis management (CM) and business continuity planning (BCP) (Herbane *et al.*, 2004, Herbane, 2010b), but it allows for new perspectives and insights into the conditions for doing business. From the Swedish textile and clothing (T&C) industry perspective, the average number of firms that went bankrupt during the continued global meltdown of 2007-11 escalated twofold compared to the average over 2000-10 due to tremendous pressure on the financial credit system (adapted from SCB Database<sup>1</sup>). The small and medium sized enterprises (SMEs) were the most affected of all, facing major threats to their financial performance and ultimately to their survival during the crisis. Moreover, the structural industrial statistics for T&C sectors (2000-10) also showed considerable dip, in terms of the net turnover, production value, overall profits, value addition, and total assets etc.<sup>2</sup> Such a trend was observable in other countries as well, like United Kingdom where certain studies showed low SME survival rate amidst crises (Storey, 1994, Bolton, 1971).

In such a context, study of organizational resilience (ORes) for SMEs to survive and thrive in crises becomes increasingly significant (North *et al.*, 1998, Lengnick-Hall & Beck, 2005, Herbane, 2010b), calling for research on crisis strategic planning by juxtaposing short-term and long-term crisis management and strategic management (SM) approaches (Preble, 1997, Vargo & Seville, 2011, Mitroff *et al.*, 1992, Burnett, 1998). Thus the paper derives a framework for understanding the resilience development process through crisis strategic planning (CSP) and applies it for investigating the scope for Swedish textile-related SMEs amidst economic crises. The empirical part of the paper is a compilation of the major studies along with the findings of author's research in Pal (2013, forthcoming).

## **FRAME OF REFERENCE**

Crisis strategic planning broadly covers topics from SM, CM and BCP and focuses on their inexorable linkage (Preble, 1997). The major integrated models and frameworks those deal with CSP or related concepts are discussed as the operational agility framework in Ismail *et al.* (2006), the strategic agility framework in Ismail *et al.* (2011), the five-step resilience management process in McManus (2008), the crisis strategic planning model in Vargo and Seville (2011), and possibly the most congruent one as the integrated strategic management model in Preble (1997). Pal *et al.* (2013b, forthcoming) discusses these models in detail.

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<sup>1, 2</sup> Statistiska Centralbyrån (Statistics Sweden)  
<http://www.ssd.scb.se/databaser/makro/start.asp?lang=2> (accessed 05.06.2012)

Convergences among these models/frameworks are observed as they adopt fairly similar stages: (i) auditing SME's environment through either turbulence analysis, STEEP (social, technological, economic, environmental and political) analysis or situation awareness (also highlighted in McManus *et al.* (2008), Preble (1997)), (ii) vulnerability or impact analysis and prioritization (Ismail *et al.* (2011), Ismail *et al.* (2006)), (iii) understanding the differentiation factors through leadership analysis or organizational component/business mapping – to identify the critical success factors (CSFs) (Rockart, 1979, Rockart & Bullen, 1981, Leidecker & Bruno, 1984) and necessary organizational capabilities/competences (Porter, 1998, Barney, 2002), (iv) positioning the organization in terms of competitive strengths and weaknesses through either capability analysis or by adjudging the organizational preparedness – in terms of resources and dynamic capabilities to yield resilience (Schulman, 1993, Gittell *et al.*, 2006, Vogus & Sutcliffe, 2007, Freeman, 2004, Sheffi, 2007) or through organizational learning (Weick & Sutcliffe, 2007, Senge, 1990, Edmondson & Moingeon, 1998, Vossen, 1998, Sheffi, 2007), (v) setting targets and selecting growth options, assessing and prioritizing them, and finally (vi) implementing them either by 'evaluating and implementing growth options', cross-impact analysis or through adaptive capacity development (Preble, 1997, Ismail *et al.*, 2011, Vargo & Seville, 2011). Such strategy development process is articulated as the combination of long-term objectives aimed at either offensive SM for growth or for business continuity, along with defensive capabilities of CM and disaster recovery. Hence, this part of the framework derives concepts related to growth strategies (Ansoff, 1957, Li & Tan, 2004, Li *et al.*, 2011), crisis management and Business Continuity Management (BCM) (Herbane, 2010b, Herbane, 2010a, Herbane *et al.*, 2004, Engemann & Henderson, 2012, Mitroff, 1994). The steps (iv-vii) also set out an assessment of required organizational structure for enabling resilience as highlighted in figure 1. Finally the organizational resilience is measured and monitored as the outcome of the process.

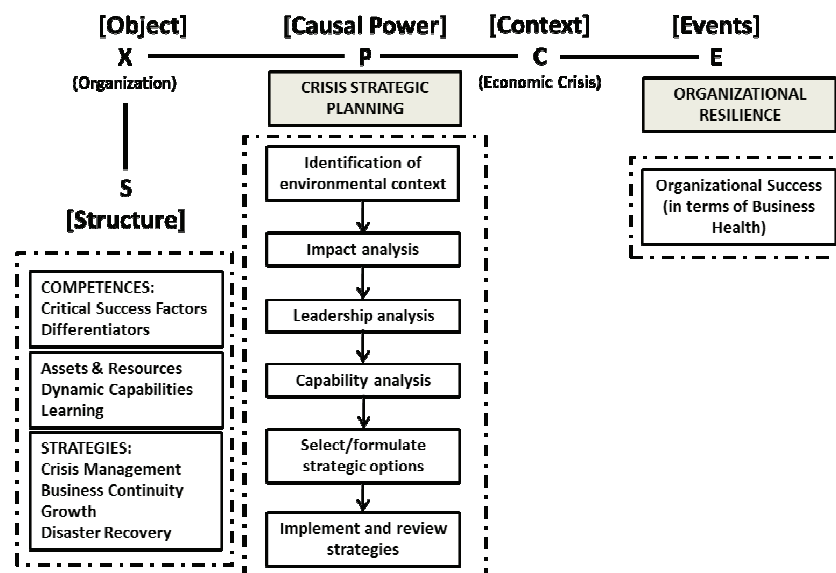


Figure 1. Proposed resilience development framework (Pal, 2013, forthcoming)

The paper, overall, summarizes the research carried out in Pal (2013, forthcoming). Thus it addresses several research questions (RQs) that can be related to the above framework diagram, viz. (i) whether resilience development a precursor for business success in crises, (ii) how can resilience be developed and monitored, and (iii) what are the antecedents and the key strategic initiatives of resilient SMEs and how do they differ from less resilient ones?

## METHODOLOGY

The paper is a conceptual review of the research "Organizational resilience through crisis strategic planning" (Pal, 2013, forthcoming). It summarises the findings of the thesis applied to Swedish textile-related SMEs. The thesis develops its empirical underpinnings from the investigations in 5 studies described in Table 2.

Table 2. Data Synthesis – adapted from Pal (2013, forthcoming)

	Data Collection	Data Analysis	Relation to framework
Study 1	Convenience- and judgement- based non-probabilistic sampling Survey responded by 42 Swedish T&C firms	Descriptive and inferential statistical analysis	Highlights the research gap existing in 3-DCE model of organisational structure to yield CSFs in dynamic environments. Proposes an extended 3-DCE model to foster resilience
Study 2	Criterion-based non-probabilistic sampling, convenience sampling Secondary data (annual reports) from 20 Swedish textile-related SMEs; Single case study	Quantifying resilience – Coding system developed via abduction Resilience management – Thematic coding based on 5-step resilience management process by Allen and Davis (2010)	Uses Altman's Z-score as a multivariate indicator of business health for relating to both short- and long- term goals of a firm. Z-score transition profile assesses business health and resilience for operationalizing success
Study 3	Theoretical sampling Semi-structured interviews with 8 SMEs; <b>Survey</b> ; Secondary financial data (annual reports)	Thematic coding of data along the resilience antecedents followed by cross-case analysis for emergent pattern recognition	Identifies the antecedents (tangible and intangible assets and resources) for developing robust organizational structure and their differential degrees of influence on economic resilience
Study 3	Theoretical sampling Semi-structured interviews; Secondary financial data (annual reports)	Thematic coding for data categorisation along multi-strategy initiatives and connecting them to types of resilience followed by comparative pattern analysis to develop a CSP model	Identifies the strategic initiatives that differentiate the response repertoire of the resilient and the less resilient SMEs during crises and develops a multi-strategy based CSP model
Study 4	Critical case selection Single case study (through multiple interviews, surveys and assessment of secondary data)	Thematic coding along a 6-step CSP-based resilience development framework (deepened case analysis, coding along 6 steps and weaving a narrative)	Outline the resilience development process for SMEs using generic tools modelled through CSP framework thus integrating both adaptive and planned initiatives for sustenance and growth over a timeframe of development

A mixed methodology was adopted based on quantitative statistical analyses, at first, followed by qualitative work based on surveys, interviews, case studies and secondary data. Data analysis was conducted through certain thematic coding principles. Overall, the resilience development processual framework was developed along a CR-GT view of causation (Lee, 2012) as highlighted in figure 1, based on the relationship between/among object (structure), causal power, context and the event. This combines a processual approach (Pettigrew, 1997), causation based on critical realism (Sayer, 1984) and grounded theory method for providing analytical explanation (Glaser & Strauss, 1967).

## RESULTS AND FINDINGS

The findings are structured along the following studies:

**Study 1:** Study 1 showed that for mapping organizational competences along a 3-DCE domain it is necessary to incorporate intangible value propositions into the 3-DCE model to generate an 'extended 3-DCE' framework for mediating operational performance and hence organizational success (Pal & Torstensson, 2011). This also corroborates that a trajectory/commonality exists in synthesizing these CSFs for leading to success.

**Study 2:** It was evident that, in general, the *healthy* firms showed higher average values of most of the univariate financial ratios compared to the *unhealthy* ones though not in all periods thus suggesting higher reliability of using a multivariate score, like the Z-score. For example, during the 2007-09 financial crisis, four of the studied firms in *healthy* business state showed higher average values of all the univariate ratios over seven firms those were unhealthy throughout the crisis.

The contributions of the five important univariate financial ratios to the resilience level in different periods were also assessed for the studied firms. For example, two of the analysed firms showed higher liquidity, leverage, and solvency during the recent financial crisis, compared to the others for maintaining a *healthy* state, while for two other firms liquidity, profitability and capital-turnover contributed to their resilience development (in the period 2004 to 2006) so that they could be 'partly' resilient in the crisis. A fifth firm maintained a high resilience by generating higher capital-turnover and liquidity during the 1990s economic crisis. This yielded a high recovery potential for the firm after the crisis, and it could also generate higher liquidity, sales and profitability.

On the other hand, it is evident that the firms not resilient during different crisis periods were poor in terms of the economic ratios, compared to the overall average for all the studied firms. Lack of liquidity, capital-turnover, leverage, profitability, etc. resulted in poor resilience, particularly for three of them, which were totally non-resilient during all the studied periods. One of those showed negative working capital for six consecutive years (2004 to 2009) and negative EBIT for four consecutive years (1989 to 1993), while another firm generated negative profits for five consecutive years (2005 to 2009), proving their distress conditions during crisis. This characterizes organizational resilience in terms of attaining favourable business health related to key financial ratios.

**Study 3:** Findings provided insight of how the firms considered resourcefulness, viz. cash flow and investment finance, relational networks and material assets, along with 'dynamic competitiveness' through strategic and operational flexibility to be key enablers of resilience and financial performance. Cash flow constraint arose due to too much borrowing of foreign currency, sudden currency devaluation, decrease in sales turnover etc. affecting the liquidity ratios and cash reserves in many ways (Pal *et al.*, 2013a). Investment finance constraint was also evident in firms due to misjudged business ventures, bankruptcies etc. and



was aggravated by poor credit support from banks. The analysis also emphasized several factors contributing to the shrinking supply and customer relational networks of SMEs, as pointed out by the owners/managers (Pal *et al.*, 2013a). Additionally, firms were also compelled to depreciate their stock values and think of consolidated internal restructuring for higher efficiency planning. This considerably affected the make-buy decisions. However, lower flexibility in inventory management for handling raw materials or finished goods, lower flexibility in manufacturing or make-buy decisions also resulted in a lack of resilience by affecting profitability and liquidity. On the contrary, one of the firms followed efficient small batch manufacturing to improve the production efficiency, reduce lead times and be sufficiently lean to enhance operational agility. Responses also highlighted the indirect influence of the 'soft' learning and cultural aspects, like attentive leadership and collectiveness, on economic resilience, considered tacit and ingrained in SMEs. Most of the SME owners considered that these 'soft' aspects do not facilitate economic resilience directly. However, some of the firms considered 'lack of cross-functional training', 'silo structures', and 'lack of formal education' as factors inhibiting resilience during crisis. The role of leadership and management decision-making were influential factors in facilitating resilience during the recent crunch, while firms those could break-away from the 'command and control culture' were more entrepreneurial and open, and showed better economic resilience.

Additional process initiatives (growth and business continuity strategies) were also emergent patterns to rightly allocate the resilience antecedents (Pal *et al.*, 2013a). The resilient firms showed better short-term CM strategies, via fast cost-cutting measures like retrenchment, reduce customer and supplier base, ramp down production etc. The less resilient firms, on the other hand, lacked strategic readiness due to resource scarcity. Almost none of the firms executed crisis-based growth strategy. The resilient firms differed from the less resilient ones, mostly in terms of long-term strategic initiatives showing continuity planning by unique initiatives to improve cost-effectiveness, like delocalization of manufacturing, continuous improvement etc., and in terms of growth strategies as well, like market penetration by increasing sales and product ranges, long-term diversification strategies through market expansion, and long-term transformational initiatives by focusing more on acquisitions and production outsourcing.

**Study 4:** Along the CSP model, an understanding of the crisis environment (through turbulence, impact and SWOT analyses), for evaluating and allocating resources and assets (through capability analysis) for proper strategic initiatives (strategy development and review) is essential for resilient financial performance (Pal *et al.*, 2013b, forthcoming). The study reveals a CSP-based roadmap using simple tools and techniques that should be followed by SMEs for resilience development. A sincere practice of the framework would potentially improve both responsiveness and preparedness in an integrated way and review its impact on financial performance to underpin resilience. Study 4 showed how the case firm translated from a lower to a higher level of resilience by understanding the transition process along the CSP model.

## **ANALYSIS AND DISCUSSION**

The above findings can be grouped under the following four points to answer the RQs.

### **The need to design for resilience**

Development of the building blocks of 3-DCE perspectives along with complementary value systems based on intangible 'soft' aspects of culture and

learning etc. (Repenning & Sterman, 2002, Molnar, 2004, Marr, 2007) fosters capabilities/competences to develop a multitude of CSFs for yielding business success. This calls for designing resilience in an organization to cope with a dynamic environment thus proposing a shift from component-based view to system's view towards organizational success (Pal & Torstensson, 2011). This proposes an extended 3-DCE framework for organizational success in dynamic environments fitting the need to design for resilience, answering RQ 1.

### **Quantifying resilience by devising a measurement index**

While organisational resilience generally has been considered a qualitative entity, the recent research (Pal *et al.*, 2011) attempts to relate resilience to the degree of business health in terms of economic viability by adapting the framework proposed by Allen and Davis (2010). This includes identification of the existing financial indicators and redefining them into a new set, viz. liquidity, leverage, profitability/operating efficiency, solvency and activity for indicating business health in terms of multivariate Altman's Z-score (Pal, 2013, forthcoming). Study 2 revealed that the firms classified as 'not at all' or 'hardly' resilient in the specified time periods were, in general, poor in terms of business health and had a risk of slipping into distress situations, anytime. This complements the work in Sundström and Hollnagel (2006) describing a similar phenomenon of catastrophic organisational failure as the company slipped into an unhealthy and subsequently a catastrophic business state, due to market events, illustrating lack of resilience. Research works by Bordia *et al.* (2005), Epstein (2004), de Waal (2008) and many others established that resilient organizations show better financial performances and are the healthiest. On the other hand, a number of investigated businesses consistently showed lack of resilience, staying on an average just two years in the healthy state compared to that of eight years for rest of the firms, between 1989 and 2009. This can be attributed to lack of financial resources and assets in terms of liquidity, capital-turnover, leverage, profitability etc. resulting in poor resilience characteristics (Pal, 2013, forthcoming, Pal *et al.*, 2011). The discussion answers how to monitor economic resilience.

### **Organizational structure of resilient textile SMEs**

Several key patterns emerged out of the analyses of studies 3 and 4. These highlight the key role of organizational structure (competences, resources and capabilities, and strategies) for resilience development in crises as follows: (i) Financial resources: Cash flow was considered as a critical enabler of SME resilience, along with investment finance, as also highlighted by Vossen (1998), Van Gils (2005), Gittell *et al.* (2006) and others. Investment finance problems significantly hindered resilience development as also demonstrated by Sullivan-Taylor and Branicki (2011), while good bank support led to better economic resilience due to higher liquidity and better leverage. (ii) Relational networks: Freeman (2004) analysed how close relationships in working with the suppliers, customers and marketing partners to get more order volumes were essential enablers of resilience. Such a pattern was observable amidst the credit crunch for contributing towards better capital-turnover (Pal *et al.*, 2013a). On the other hand, lack of external support was a potential resilience inhibitor for SMEs (Fassoulsa, 2006). This considerably increases the supply chain vulnerability during crisis. (iii) Material assets: Asset problems aggravated by price hikes, stock lots, decrease in orders etc. are common during crisis (Pal *et al.*, 2013a). Such constraints were evident during the credit crunch and were considered to be potential resilience inhibitors, considerably affecting firms' profitability, sales turnover and leverage. (iv) Strategic flexibility: Rapid decision-making, effective

internal communications, fast learning and ability to quickly adapt strategies are critical aspects in SMEs (Vargo & Seville, 2011, Sullivan-Taylor & Branicki, 2011, Vossen, 1998). Such flexible strategic planning lay in devising rolling long-term plans to maintain necessary readiness even during crises. Strategic flexibilities are also essential to devise changes in organizational design or business model by delocalizing production or by shifting product core, etc. (Pal *et al.*, 2012). Overall, this is essential for growth aspects in firms for higher capital turnover. (v) Operational flexibility: Resilience can be built through operational flexibility in many ways (Peck, 2006, Sheffi, 2007). However this is less observable in case of SMEs (Thun *et al.*, 2011). Even though Sheffi (2007) and others have emphasized the role of operational and structural flexibilities for building resilience only in case of large firms, few studies showed the necessity for SME resilience as well. Study 3 highlighted the role of structural flexibility in case of manufacturing SMEs for better profitability and cash flow leading to economic resilience. Control over own manufacturing pipeline can lower lead-time and improve inventory management. On the contrary, lower flexibility can affect firms' profitability and liquidity as was investigated by Thun *et al.* (2011). (vi) Continuous improvement: Quality issues maintained through continuous improvement was a key antecedent of resilience also highlighted by Ismail *et al.* (2011) and Kumar *et al.* (2011). (vii) Learning and cultural aspects: Collaborative decision-making, capacity for fast learning and rapid internal communications supported by powerful CEO and top-management leadership made SMEs learning-oriented for enabling resilience (Vossen, 1998, Bourgeois & Eisenhardt, 1988, McManus *et al.*, 2008, Seville *et al.*, 2006, Penrose, 2000) as was revealed in study 3 and 4.

The above-mentioned resilience antecedents are complemented by a multitude of strategies (short-term and long-term) that needs to be developed for proper resource allocation. The strategies significantly demonstrated by the resilient SMEs were as follows: (i) Crisis Management: Short-term CM strategies are adaptive and consist of various incremental actions or 'fire-fighting' responses (Smart & Vertinsky, 1984, Cater & Schwab, 2008). Studies by Pal *et al.* (2012) and Pal *et al.* (2013b, forthcoming) highlighted such CM strategies demonstrated by the resilient firm(s) through retrenchment and cost-cutting during the crises. However, the less resilient firms also showed some level of CM but lacked flexibility in the production to respond fast to a decrease in order-volume. (ii) Crisis-based growth: Generic growth strategies, like breadth-on-top-of-depth (BTD), transformational or diversification are essential to foster resilience in firms when developed and exercised during crisis (Li & Tan, 2004, Li *et al.*, 2011). Crisis-based growth strategies were observed in the resilient firms in studies 3 and 4 (Pal *et al.*, 2012, Pal *et al.*, 2013b, forthcoming). (iii) Long-term business continuity: BCM incorporates strategies for organizational survival by coping with crises or by building options/plans involving long-term development of competitive advantages and value creation (Vargo & Seville, 2011, Herbane *et al.*, 2004). Study 3 highlighted some of the key business continuity initiatives taken by the resilient firms through delocalization of production, or cost-cutting by implementation of various quality control measures (TQM, CI, lean) etc. (Pal, 2013, forthcoming, Pal *et al.*, 2012). Similarly, Pal *et al.* (2013b, forthcoming) highlighted significance of business consolidation by the case firm to yield resilience during crisis. (iv) Long-term growth: BTD is a significant growth option in firms via market penetration and process capability extension (Ansoff, 1957). Such strategies were demonstrated by the resilient firms through long-term brand promotion and development for market penetration (Pal *et al.*, 2012). Product range adjustment as a BTD strategy also resulted in resilient financial performance. Pal *et al.* (2013b, forthcoming) highlighted the role of BTD strategies necessary for market penetration and for contributing favourably to economic resilience by increasing the company's capital turnover and profitability.

Diversification, on the other hand, is also essential to achieve growth by gaining access to complementary assets (Kale *et al.*, 2000, Li *et al.*, 2011, Sarkar *et al.*, 2001). Development of various inter-organizational relationship (IOR) networks was evident in the resilient firms in study 3 (Pal *et al.*, 2012). Furthermore, transformational strategies are also essential to expand the boundaries of firms and to fully employ under-utilized resources. Such strategies were observable in most of the resilient firms of study 3, essentially through transformation of business model (Pal *et al.*, 2012). Study 4 also highlighted the role of long-term transformational growth strategies developed by a firm through a shift in business model in favouring resilience development (Pal *et al.*, 2013b, forthcoming).

Such multiple strategic initiatives are essential for developing a model for crisis strategic planning for categorizing firms along four difference types of resilience viz. *latent*, *planned*, *adaptive* and *dynamic*, along two dimensions characterized by low and high degrees of planning and adaptation, respectively (Pal *et al.*, 2012). It was observed in study 3 that resilient Swedish textile-related SMEs mostly showed *planned* resilience in financial crises through long-term continuity plans and growth initiatives via market penetration, diversification and transformational initiatives. The less resilient firms, on the other hand, lacked strategic readiness due to resource scarcity. Such a model serves as a reliable benchmarking tool to measure resilience and position the firms in a competitive landscape during crises to evaluate their strategic responses (Pal *et al.*, 2012). This answers RQ (iii) and also contributes towards answering how resilience can be developed.

### **Crisis strategic planning for resilience development**

Resilient firms need to juxtapose a set of inconsistent strategies like effective planning and adaptability every time which makes the role of crisis strategic planning critical (Vargo & Seville, 2011, Pal, 2013, forthcoming). However, lack of a proper crisis strategic planning mainly due to slack resource constraints is deemed to be a key inhibitor to resilient functioning in SMEs. The CSP-based resilience development framework proposed in research is prescribed along six generic steps using very simple and strategic tools and techniques for easy use and implementation by SME practitioners. This helps in establishing a 'one-size-fits-all' approach to resilience development by, firstly, identifying the environmental contexts, as was done in studies 3 and 4 (Pal *et al.*, 2012, Pal *et al.*, 2013b, forthcoming), followed by an impact analysis in an SME context in terms of key financial indicators. This was evident in the case firm of study 4 (Pal *et al.*, 2013b, forthcoming). Next, the leadership analysis conducted to adjudge the differentiation factors and CSFs serving as valuable inputs to environmental analysis, resource analysis and in the strategy development process was evident in study 4. The case firm showed moderate levels of CSFs during a period of resiliency while low levels of CSFs in the period of non-resiliency (Pal *et al.*, 2013b, forthcoming). The next step is capability analysis using SWOT which help firms to be resource-focused (both 'hard' and 'soft' assets) to effectively allocate and utilize them dynamically for strategic positioning in crises (Barney, 1991, Teece *et al.*, 1997). However, this is a critical problem for SMEs (Ingirige *et al.*, 2008, Herbane, 2010b) and its critical role was investigated in studies 3 and 4 (Pal *et al.*, 2012, Pal *et al.*, 2013b, forthcoming). Step 5 involves selection/formulation of strategic options by taking an integrative view towards SM, CM and BCM (Mitroff *et al.*, 1992, Preble, 1997, Burnett, 1998) and were evident in studies 3 and 4. The resilient firms were significantly better in development and selection of strategies compared to the less resilient ones (Pal *et al.*, 2012, Pal *et al.*, 2013b, forthcoming). Finally, step 6 is about implementation and review of the strategies to formalize the actions taken to

determine whether the strategic initiatives were achieved as also suggested by Preble (1997). This was evident in the case firm of study 4 (Pal *et al.*, 2013b, forthcoming). This sufficiently answers how resilience can be developed.

## **CONCLUSION**

The CSP model developed to foster organizational resilience proposes a strategic roadmap on how to understand the operating environment, devise capabilities and formulate, implement and evaluate strategies during crises and is useful for SME owners and managers. Another major understanding from the research is how firms can develop their resilience potential by tuning their strategic assets and capabilities. For the investigated SMEs the key antecedents were: a) investment finance and cash flow, b) material assets and networking, c) strategic and operational flexibility, and d) attentive leadership (Pal *et al.*, 2013a). These are essential to generate a broad repertoire of both business continuity and growth strategies by harnessing the inexorable linkage of effective planning and adaptation strategies. For the investigated SMEs, resilience was established through better short-term CM through higher operational flexibility and better long-term strategies through BCP, along with growth strategies via market penetration, diversification and transformational initiatives (Pal *et al.*, 2012). This in combination with the conceptualization and operationalization of a Z-score based economic resilience model (characterizing business health) has crucial practical implication in developing a reliable benchmarking tool for firms for measuring resilience and subsequently enhance it. Practical implications of the research also lie in understanding where and how to invest to develop unique strategic repertoire in crises. This can have a strong impact on business resilience by addressing a range of crisis-related problems.

However, limitations of the present research exist from the methodological and theoretical perspectives, considering that the concepts of competitive advantage or that of organizational dynamics (high reliability theory) etc. have not been focussed in detail. There is also a lack of more direct observational studies. Furthermore, the role of external factors like legislation, globalization etc. is considered beyond the scope of the present research.

Future research are inevitable, particularly observable with the increase in the attractiveness of SME competitiveness research under the European Union Commission (Pal, 2013, forthcoming).

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# ENABLING ROBUSTNESS THROUGH SUPPLY CHAIN RESILIENCE

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## **Abstract**

Several natural and man-made disasters have shown the high fragility of global transport chains. To cope this fragility transport logistics providers (TLP) have to pass a serious paradigm shift: to strengthen their transport chains TLP's have to implement the robustness as well as the resilient engineering approach to make them resistant to internal and external influences (noise). The present paper focusing on resiliency in organizations and will provide an overview of the methodologies and tools of resilient management. As you will see communication and timely information sharing are a basis in transport logistics and supply chain management. Therefore Intelligent Cargo (iCargo), an European Union project, which aims to mentioned requirements will get introduced.

## **Definition**

Robustness and resiliency are interrelated terms: In general robustness is the main target in supply chain management [35] and is defined as the capability of a firm to manage regular fluctuations in demand efficiently under normal circumstances regardless of the occurrence of a major disruption [9]. Robustness is also associated with reliableness. "For a system to remain reliable, it must somehow handle unforeseen situations in ways that forestall unintended consequences" [33]. Resilience denotes (a) the ability to handle such unforeseen situations and (b) the ability of a system to return to its original (or desired) state after being disturbed: "Resilience describes for companies their ability to, and speed at which they can, return to their normal performance level following a disruption. But the most important is not only that the supply chain is robust enough to continue operating in a risky environment, but also to turn this resilience into competitive advantage [26]. "To be resilient also means to utilize the change that is absorbed" [33]. Resilience is related with agility and flexibility [20]. Special in turbulent circumstances organizations need to be flexible. The main idea behind robustness is to create undisturbed, strong and resistant processes. However the main idea behind resilience is to cope threats which affect a process. In other words, robustness will maintain intact its structure, while resiliency shall adapt itself to find a (new) steady position [19] before, during and after a disruption. Therefore a robust supply chain is always resilient (and vice versa).

According to the system theory the robustness approach find its place in parameter design which is linked to methods like process engineering and process optimization. This shall guarantee "the unusual capacity to produce collective outcomes of a certain minimum quality repeatedly" [33] (even in a case of disruption). The aim is to improve and stabilize the quality of a system through quantifiable, measurable and improvable numbers and figures. Robustness depends on the "lack of unwanted, unanticipated, and unexplainable variance in performance" [33] which shall be stabilized through process engineering, process optimization and resiliency. Resiliency refers on the one hand to the "prediction and prevention of potential dangers before damage is done" [33] (anticipation) and on the other hand to the "capacity to cope with unanticipated dangers after

they have become manifest, learning to bounce back” [33]. Its aim is rightly to avoid or reduce of the exposure of noise factors and crisis situations (and to the impact from those situations) [6] through implementing risk awareness methods. The following figure visualizes the embedment of the robustness and resiliency approach in the system theory.

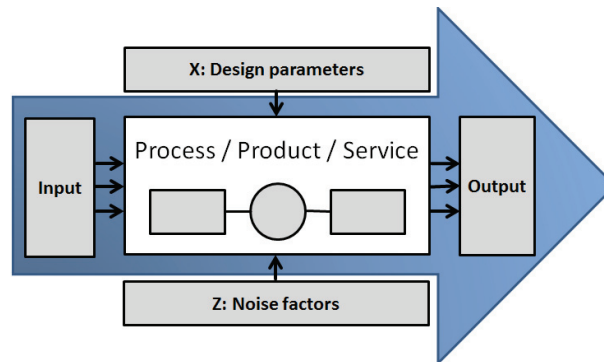


Figure 1: System theory<sup>2</sup>

The focus of this paper is on the term resiliency and resilient management. Therefore the following chapters will exclusively examine this term, its ingredients and impacts on business.

### Resiliency / Resilient Management

Resiliency or resilient management means to eliminate internal and external noise factors which affect a system like an organization, process, supply chain, etc. Resilience focuses on the methodologies risk management, business continuity management (BCM) and crisis management. Risk management describes the anticipation method and is in general all about risk mitigation and prevention. However BCM is the capacity to cope with anticipated as well as unanticipated events. In general BCM it is all about risk prevention, preparedness, response, recovery and rehabilitation before, during and after a disaster hit. In the center of BCM are fast recovery and being better positioned than competitors to deal with – and even gain advantage from – natural hazards and man-made disruptions [25]. Crisis management is on the one hand (a) the execution of BCM plans after an anticipated event and (b) the improvisation after an unanticipated hit the company. Also organizations that are able to act on hazards are also able to see those hazards and think about them [33]. Therefore a further important step in resilient management is to increase the psychological and organizational readiness to respond to crisis situations and to recover from those situations that cannot be removed, reduced or avoided [6]. Following these two cornerstones of resiliency will get visualized. Therefore resiliency enables a better support for the unpredictability [19].

### Reduction of the exposure of crisis situation

Risks are always associated with uncertainty and randomness and, formulated to the extreme, every event constitutes a risk if it is uncertain as well as it has impacts of the achievement of the corporate goals. Risks arise from hazards and the exposure to the situation and are classified with the following two factors:

- that an adverse event or hazard will occur (probability / likelihood) the probability
- of the adverse event (magnitude / severity) the consequences

<sup>2</sup> Own table. Reference to: [14]

These two factors are the basis of the risk matrix where risks get categorized. The following figure visualizes this matrix.

Probability / likelihood	Very likely	5	20	45	80	125
	likely	4	16	36	64	100
	Moderate (unlikely)	3	12	27	48	75
	unlikely	2	8	18	32	50
	Very unlikely	1	4	9	16	25
		insignificant	minor	moderate	serious	disastrous
		Magnitude / severity				

Figure 2: Risk matrix<sup>3</sup>

The general approach to this matrix is that the green highlighted fields represent acceptable risks which do not need any specific measurement. But the higher the axes hike the higher the need for specific risk measurement. According to this approach the red highlighted fields represent risks that should either be avoided or transferred [23]. In the first view risk management is the right method to cope these threats.

### Risk Management

Risk management is a systematic, value- and success-orientated approach for the anticipation, analysis and handling of risks. With other words: risk management "is the practice of systematically identifying, understanding and managing of risks encountered by an organization" [34]. Risk management shall help to prevent the occurrence of hazards (e. g. by identifying of the potential vulnerabilities), to minimize the negative impacts that it triggers (e. g. by eliminating the cause), to transfer the resulting costs, or to accept and retain the possible consequences [23] by initiating appropriate solutions / measures. Consequently risk management, as a preliminary tool of resilient management helps to build more robust business processes, ensuring that key risks are managed in a way that enhances the interests of shareholders and key stakeholders [1]. But "usually, risk management approaches look at things in the rear view mirror – [...] take past incidents and project from them future probability" [7]. But to detect and cope threats with low probabilities and high impacts risk management fails. These threats are future events and represent irregular and unexampled events [12] which are represented by the fields with number 16, 25, 32 and 50. For example: "An accident or natural event of catastrophic magnitude can strike unexpectedly – whether it's an earthquake, typhoon, tornado, hurricane, blizzard, flood, fire, or some other disasters" [5]. Events with low probability and high consequences trigger serious crises situations and affect the whole company and transport network and its fundamental goals – from short term breakdowns till bankruptcy. The loss of technology, people, facilities, and/or critical third parties is preprogrammed [16]. To protect the system advanced methodologies have to be implemented because: the less adequate the process and activities directed at a crisis the more likely it is that the crisis will go out of control [30].

### Business Continuity Management

Generally the effort spent in handling of crisis events (crisis prevention, crisis management, (how it was dealt with, what was done and what happened)) is called business continuity management or crisis management [6] and, ideally this process begins before the disruption arises through an evaluation of the risks

<sup>3</sup> Own figure. Reference to: [16]

(Risk assessment and/or Business Impact Analysis<sup>4</sup>) [5] & <sup>5</sup>; [6]<sup>6</sup>; [31]. Therefore on the one hand risk management and business continuity management (BCM) “need to be considered as part of an integrated process” [34]. BCM can set up on the results of risk management. On the other hand, contrary to risk management, BCM handle with the future events through contingency planning and scenario technique. Contingency planning do not only deal with physical crisis – contingency plans can be designed to cover all types of incident that the organization itself has decided could be disastrous in future for it and in need of structured, resourced and co-ordinated responses [8]. “This term has some connections to military strategy, where different elements of an impending battle cannot be predicted with certainty, so each plausible variations is a contingency [...] and a plan for dealing with each such contingency is formed” [11]. Therefore BCM activities focus on the processes that need to take place after an event or disaster occurs; the objectives of those processes are to restore the business to normal operations as efficiently and effectively as possible [24] and build a company’s overall defense against potential threats, whether those threats are financial, technical, social, political or environmental in nature. Simplified visualized a BCM process consists by four steps [22]:

- **‘Initiation and redefining’** is known as strategy formulation which shall help to implement BCM into the existing organizational processes. The challenge in this phase is to find the organizational support (financial and leadership) and a clearly stated commitment from the board of management to remit for ongoing continuity planning activities. An argumentation problem will be that BC programs cannot truly provide return on investment, because BCM do not have a return. But in sense of the continuity of business and business reputation, it's better to have a somewhat costly plan for an emergency that is not used than to have to explain post-catastrophe why you weren't prepared<sup>7</sup>.
- **‘Planning for business continuity’** symbolizes the beginning of the BC program. The goal of this stage is to improve resilience by protecting the organization through prevention and preparedness. This stage consists by a business impact analysis (BIA), which is similar to a risk analysis. “BIA offers a preliminary analysis of some of the idiosyncrasies of every organization’s resources, systems and operations” [3] and helps to understand the company and its environment. Through this internal and external analysis business continuity plans (BCP) for prevention, protection, preparedness, mitigation, response and recovery [18] can get developed. BCP should be understood as creating options for the emergency managers, not dictating specific actions [29]. The reason to have BCP’s is to consider that everything you need to consider while making decisions under stress.
- **‘Implementation’** refers to embedding the BC approach and the continuity plans into the organization – build and train a team that flexibly covers response and recovery actions. This establishes a functional response and recovery management [6].

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<sup>4</sup> “When risk and impact analysis are combined, a useful tool (often called a methodology) is formed that helps preparation for crisis management” [6]

<sup>5</sup> “Effective and rapid signal detection and action triggers are an essential part of good crisis management”, [6]

<sup>6</sup> “Scanning the sources of risk [...] and conducting an audit of the things that could grow into crisis are the first step of crisis management” [5]

<sup>7</sup> “It is often assumed that the cost of building resilient enterprises can be justified by estimating the cost of a disruption and making the case that this expense can be avoided if the organisation is prepared for the crisis”. → [28]

- **'Operational Management'** refers to the instigation of response and recovery activities – the deployment of the continuity plans in test and training as well as in case of an emergency. This action develops community-based and organization-wide readiness for response and recovery management, and enhances resilience [6].

But no matter how good the BCM process might be, it is impossible to detect all disruptions [31]. Therefore planning for events with low occurrence and high probability can be divided into two clear categories [25]:

1. preparing for specific disruptions (irregular threats)  
There are many similar low-probability but devastating events that might take place; and cannot prepare for all of them. This kind of threat provides an understood, but still challenging problem [12].
2. preparing for the unknown (and in many cases unknowable) disruptions  
These kind of threats are "marked by events that are so awesome or so unexpected that they require more than the improvisation of" [12] irregular threats. They require a shift in mental framework. It may appear impossible that something like the event could happen". Whereas irregular threats are basically a scale-up of regular threats, unknown events pushes the responders outside of their collective experience envelope.

Special in case of number two the powerlessness promotes further interest in improvisation which is called in this paper crisis management.

### ***Crisis Management***

In general crisis management has two different meanings. First in case of the occurrence of an anticipated threat crisis management is the execution of existing business continuity plans. In this case crisis management mean "quick action that deflects a triggering event as it unfolds rather than delayed action that mops up after the triggering event has run its course" [30]. Second the term crisis management is also reserved for events that are unanticipated or unplanned for whatever reason and causing a breakdown in business continuity [31]. While in case one, preparations for specific disruptions can be prioritized and specific measures can be taken in the occurrence of unanticipated events crisis management needs adjustment on the threat and thus improvisation. In general resilient organizations have the capability for improvisation and the capability to combine it which enlarges the size of its action repertoire [33] (e. g. existing BC plans). The importance of improvisation point out Wildavsky (1991): "Improvisation in overall capability, i. e., a generalized capacity to investigate, to learn, and to act, without knowing in advance what one will be called to act upon, is a vital protection against unexpected hazards" [33].

While risk management is a managerial discipline BCM (incl. crisis management) is a holistic and organization comprehensive management approach. "To be effective, BCM must become part of the organization's culture and core values. Regardless of the size of the organization or the sector in which it operates, BCM must become embedded in the organization's routine operations and management process" [2]. Therefore BCM includes the commitment of the strategic management level and influences the organizational politics, targets, architecture, guidelines, concepts and measures. The embedment of BCM is visualized in the following figure.

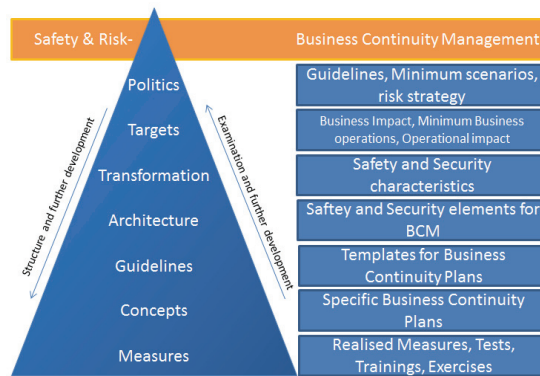


Figure 3: Business Continuity Management<sup>8</sup>

But BCM is not only the mitigation of risk and threats: it is the basis of resilient management; the top is the psychological and organizational readiness to respond to crisis situations. This capacity for resilience is found in an organization's culture and capability for change.

### **Psychological and organizational readiness to respond to crisis situations**

An organization or "system should only be called 'resilient' when it is tuned in such a way that it can utilize its potential abilities, whether engineered features or acquired adaptive abilities, both in expected and unexpected situations" [4]. Organizations which are able to act on hazards are also able to think about them [33] and therefore should have the capability for change to better accommodate changing demands [13]. "Resilience then concerns the ability to recognize and adapt to handle unanticipated perturbations that call into question the model of competence, and demand a shift of processes, strategies and coordination" [13]. Probably change is the most challenging activity in resilient management and consists by organizational culture and behaviors, communication (information flow) and change management. Ironically change itself consist a certain level of risk – but without change and its accompanied risk there could be no progress [14]. Change is an on-going process which will never be finished and organizational mindfulness will never be totally achieved.

### **Organizational culture and behavior**

Culture and behavior are subjected to organizational learning. But learning also presumes unlearning, that there is a cognitive and affective resistance to be overcome [17]. For systems it is easier to lose mind than to gain [32]. What organizations can do is to introduce 'heuristics of fear' in order to 'build a vision of the future such that it triggers in the present time a behavior preventing that vision from becoming real' (Dupuy, 2002). In other words, a safety manager's job is to handle irony: the core of a good safety is a self-defeating prophecy, and a whistle blower's ultimate achievement is to be wrong" [10]. According to Yossi Sheffi, "the right culture means the entire organization is deputized to serve as the eyes and ears of corporate security efforts, and can take the necessary actions to recover from any disruptions when the normal hierarchy is not operational" [27]. From a risk management perspective, the key question is how to keep concern for risk alive when things look safe [10]. A solution is to implement an environment where information is actively sought, failures cause inquiry, and new ideas are welcomed [33] ("cognitive processes that continuously reaccomplish reliability" [33]).

### **Communication / Information flow**

"When a disruption hits, speed of communications is paramount" [25]. In general a common characteristic of a resilient organization is its ability to circulate bad news and deal with the root causes quickly [28]. Good communications are at the

<sup>8</sup> Own figure; according to [F]

heart of an effective response to, and recovery from an emergency. Therefore organizations will have to rely on their local units to lead in the recovery efforts. For this purpose, as well as for dealing with smaller disruptions, companies and other organizations can build a culture of empowering lower levels in the organization to take the initiative [25]. "For example, quickly creating reliable responses can benefit from centralization and convergent decision making, but at the same time, coping with uncertainty can benefit from decentralized and divergent decision making" [15].

As you can see from above chapters, building organizations capable of risk anticipation has attracted some attention in the organizational behavior and design literature, but often not within a supply chain disruption context. Therefore research on resilient and business continuity management remains scarce in supply chain management research.

### **Solution "Intelligent Cargo"**

In the following chapter we will introduce the Intelligent Cargo approach in the context of robust and resilient supply chains. Intelligent Cargo is key corner stone in current research initiatives in the field of applied logistics and supply chain management. The European Union is highlighting this fact via the promotion of intelligent ICT solutions via the funding of various research projects under its Framework Programme 7. Amongst these the integrated project iCargo aims at efficient and sustainable global logistics through the advanced application of information and communication technology (ICT). Its approach of continuous communication, empowerment and self-steering processes refers to build up an increased resiliency in transport and supply chain networks. ICT is seen as a trigger for mindful action by building services for increasingly fluid organizational structures.

iCargo targets current limitations of existing ICT solutions by extending intelligent solutions to support innovative logistics services via the use of Intelligent Cargo. These services will be able to synchronize vehicle movements to lower CO2 emissions, re-plan supply chains dynamically in changing conditions, i.e. changes due to unforeseen incidents and deviations in planned routes, and enable collaboration of involved actors along the whole supply chain. By using the Intelligent Cargo approach business services are combined in an open freight management ecosystem, in which all stakeholders can take part in order to share relevant resources and information across company borders. The sharing is hereby powered by a semantically enabled ICT infrastructure and the Common Framework specification [37]. Within the iCargo vision five core business innovations were identified and tailored to the specific needs of the European logistics sector in cooperation with leading industry partners. *Collaborative planning* enables the iCargo ecosystem partners to participate in specific business communities and share information automatically or semi-automatically within them. Based upon this innovation the ecosystem partners benefit from new possibilities to cooperate, e.g. by combining shipments or creating re-routing possibilities in case of deviations. The business innovations in the area of *logistic chain composition* will enable companies to automatically select the best door-to-door logistic chain for a particular shipment, taking into consideration the broad variety of logistics services offered in the iCargo ecosystem. *Re-planning of logistic chains* supports all stakeholders along the supply chain in re-planning the chain according to the dynamically changing demands and to react upon incidents appropriately. The re-planning of logistics chains happens in real-time by continuous information exchange, including existing legacy systems data and also the use of smart devices with various sensors attached to the cargo and transport means itself. This business innovation enriches the ecosystem with the

capabilities necessary to detect anomalies and exceptions in the real world, thus creating more robust, re-active and sustainable supply chains. *Optimization of the use of resources* innovates the supply chain by generating real-time optimization possibilities. The situation prior to shipment and during the transportation is taken into consideration. This will be achieved by combining shipments of multiple consignees on-the-fly, handling exceptions and synchronizing movements. Finally, *monitoring the environmental footprint* is a significant challenge the transport logistics sector is facing today. Numerous initiatives throughout Europe, e.g. GreenFreight Europe or CO3, are trying to standardize the reporting process for CO2 and other emissions. However, gathering the data needed for the reporting is still a difficult task, mainly due to the high number of different transport means in modern supply chains. By providing consolidated services for this task iCargo will not only improve the visibility of the environmental footprint, but also provide the tools and services necessary to monitor emissions along the whole supply chain [36].

In order to enable the real-time information exchange which is needed for the construction of robust and resilient services along the supply chains of the iCargo ecosystem, intelligent devices are developed and deployed in the field. These intelligent devices (e.g. smart phones) have attached sensors or may be connected to existing sensors. By using the sensor data they can report anomalies and exceptions automatically. Additionally, the intelligent devices can be configured to take automated steps in re-planning and optimizing the supply chain. The intelligent devices contain a number of entities, which represent and act digitally on behalf of an item in the logistics domain. When designing an entity for these intelligent devices in a logistics ICT system, it imprints the following common logistics goals

- Having the right product (correct and without damage)
- at the right time (just in time, minimal delivery time)
- on the right place (correct destination and short route) and
- in an efficient way (also with regard to CO2 emission).

With an entity centric approach these goals are broken down directly on the entity itself, whereas an entity can be a cargo item, truck, pallet, warehouse, etc. In the derived agent based approach a homogenous environment is built to meet the earlier mentioned goals. Agents hereby describe entity centric software applications which can run, store data and take decisions based upon behalf the entity they represent. These software agents are also combined with the concepts of a digital shadow and are enablers for the Internet of Things.

In the logistics sector agents have been used in various trials in order to enable e.g. efficient proactive route planning and robust reactive routing. In the case of efficient proactive route planning the route planning is separated among different agents (e.g. on truck level) so that local decisions lead to a globally improved routing plan. In the case of robust reactive routing, agents can react locally to unexpected changes (e.g. theft, late arrival of trucks, inter-modal shifts, etc.).

Agent based approaches use standardized syntax and semantics for message exchange and message exchange protocols. It is important to notice that everything can be an agent and all agents may communicate with each other. Therefore even legacy systems can be homogenized via Adapter Agents.

## **Conclusion**

This paper highlights the methodologies of resilient management which consist by (a) the reduction of the exposure of crisis situation and (b) the psychological and



organizational readiness to respond to crisis situations. The reduction of the exposure of crisis situations consist of risk management, business continuity management and crisis management as the (a) application of business continuity plans and (b) the improvisation if an unknown or unexpected threat hit the organization. The psychological and organizational readiness consists by change management, development of mindfulness in organization as well as communication and information sharing. Therefore resilience is not only managing risks. Today resilience means being better positioned than competitors to deal with – and even gain advantage from – disruptions [25]. Additionally, ICT solutions can contribute significantly to advancing the position of a company in the market. Intelligent Cargo ICT infrastructures enable not only the constant monitoring of the whole supply chain, but also enable direct acting upon disruptions in real-time. The actions necessary in case of disruptions might even be initialized or taken automatically by Intelligent Cargo entities.

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### Characterization of robust and resilient supply chains

Robust SC	Resilient SC
„Lean thinking‘ central to supply chain strategie	Risk management central to supply chain strategy
A culture of quality awareness	A culture of risk and quality awareness
Internal quality control	Internal and external risk management
Responsive to reasonable variation in input	Responsive and capable of sustained response to sudden and significant shift in input
Supply chain velocity	Supply chain acceleration & deceleration
Low inventory levels throughout with strategic safety stocks	
Spare capacity minimised troughout	Critical path spare capacity in manufacturing, storage space and process capabiliy
Lean processes	Mix of Lean and Agile processes
Efficient processes	Effective processes
Strong	Scalabel/Adaptable
Processes are stable and under control	
Non-value adding activities and processes removed	
Supply chain output variability is minimised	

Figure 4: The characteristics of robust and resilient supply chains [21]

# **PARETO OPTIMIZATION PROCEDURE FOR A SUPPLY CHAIN NETWORK WITH TWO OBJECTIVES**

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## **ABSTRACT**

In this research, a four-echelon supply chain network (SCN) is considered comprising suppliers producing different modules, a product assembler, distributors and retailers. When designing a SCN, it is important to assess non-dominated solutions. Various methods used to solve such problems place emphasis on objectives either at the beginning of the solution process or interactively during the solution process. However, assigning weights in the beginning may lead to some valuable solutions being skipped. To address this problem, Pokharel (2008) proposed a two-objective linear programming model for decision making in a supply chain with a STEP method. Depending on the decision maker's preferences, the STEP method generates non-dominated solutions. However, the preferences chosen by the decision maker do not necessarily generate a new solution. This paper develops a solution procedure for obtaining Pareto optimal solutions for Pokharel's SCN model.

## **1. INTRODUCTION**

Recently, a supply chain with many objectives, rather than a single objective, is considered to meet diverse social needs. However, multiple objectives can be conflicting. To design a supply chain network (SCN), it is important to assess non-dominated (Pareto) solutions.

Various methods used to solve such problems place emphasis on objectives either at the beginning of the solution process or interactively during the solution process (Sujono and Lashkari, 2007; Spitter et al., 2005; Guillen et al., 2005). However, assigning weights in the beginning may lead to the skipping of some valuable solutions for a particular problem. To address this problem, Pokharel (2008) proposed a two-objective linear programming model for decision making in a supply chain that uses a STEP method presented by Benayoun et al. (1971). The STEP method generates non-dominated solutions, depending on the decision maker's preferences. However, the STEP method will not generate a new non-dominated solution if the decision maker's preference is too small.

This paper develops a solution procedure for obtaining Pareto optimal solutions for Pokharel's SCN model. The objective of this study is two-fold: to minimize cost and maximize the reliability of supply from one echelon to the next.

## **1. SUPPLY CHAIN MODEL**

Existing literature proposes many models to address issues in the SCN design. For example, Erenguc et al. (1999) reviewed the mathematical models used in production and distribution planning. In Pokharel's SCN model, a four-echelon SCN is considered, with suppliers producing different modules, a product assembler, distributors and retailers (Fig.1).

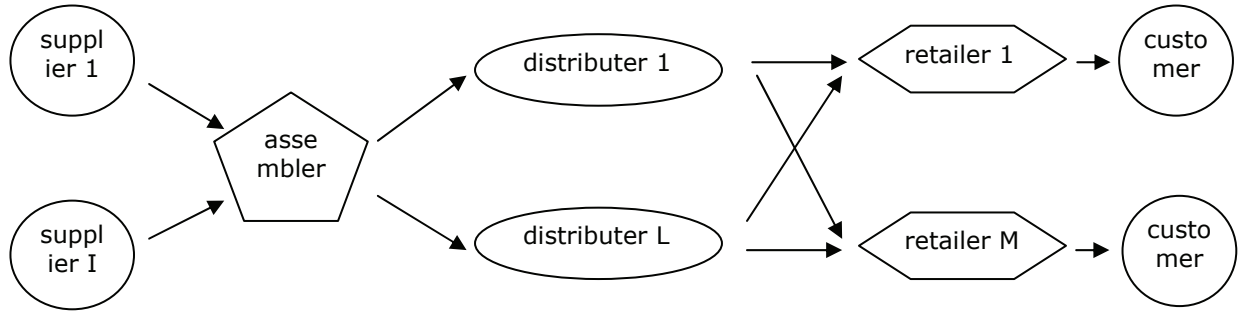


Fig. 1. SCN model

The two objective problems in this research are to select suppliers and distribution centres and allocate quantities to each of them so that retailers' demands are fulfilled.

The objective function for the minimization of total costs is as follows:

$$f_1 = \text{Min} \left\{ \sum (C_{ip} + T_{ip})x_{ip} + \sum C_A z_{Al} + \sum T_{Al} z_{Al} + \sum T_{lm} w_{lm} + \sum h_l z_{Al} \right\}, \quad (1)$$

where  $x_{ip}$  is a flow variable between supplier  $i$  and assembler for product type  $p$ ,  $z_{Al}$  is products moving from  $A$  to warehouse  $l$  and  $w_{lm}$  is products moving from warehouse  $l$  to  $m$ . The first term relates to the cost of processing a component or part or module  $p$  by supplier  $i$  ( $C_{ip}$ ) and the transportation cost of supplying the component from the supplier to the assembler ( $T_{ip}$ ). The second term relates to the cost of processing  $y$  at assembler  $A$  ( $C_A y$ ). The third term relates to transportation cost from  $A$  to warehouse  $l$  ( $T_{Al}$ ). The fourth term relates to transportation from warehouse  $l$  to the retailer  $m$  ( $T_{lm}$ ). The fifth term relates to the holding cost at warehouse  $l$  ( $h_l$ ).

The second objective function for maximization of delivery reliability is formulated as follows:

$$f_2 = \text{Max} \left\{ \sum r_i x_{ip} + \sum r_{Al} z_{Al} + \sum r_{lm} w_{lm} \right\}, \quad (2)$$

where  $r_i$ ,  $r_{Al}$  and  $r_{lm}$  are the reliability of supply from each echelon.

Pokharel considered three constraints in the SCN.

### (a) Capacity constraints

Supplier  $i$  cannot produce components or modules  $p$  more than the annual allocated capacity, as follows:

$$\rho_{ip} x_{ip} \leq \text{CAP}_{ip}, \quad (3)$$

where  $\rho_{ip}$  is unit processing time for product  $p$  at supplier  $i$  and  $CAP_{ip}$  is annual allocated capacity of supplier  $i$  allocated for product  $p$ . Moreover, the assembler cannot produce a product  $y$  more than the annual allocated capacity, as follows:

$$\rho_A \sum Z_{Al} \leq CAP_A, \quad (4)$$

$$\rho_Y Z_{Al} \leq CAP_l, \quad (5)$$

where  $\rho_A$  is the assembler's unit processing time,  $\rho_Y$  is the unit volume of assembled product  $y$  and  $CAP_A$  and  $CAP_l$  are the annual allocated capacity of the assembler and warehouse  $l$ .

### (b) Balance equations for components and products

In this research, the final product is derived by combining one component each of the unique modules:

$$\sum X_{i1} = \sum X_{i2} = \dots = \sum X_{ip}. \quad (6)$$

### (c) Market demand constraints

This research does not allow for the shortage of customers in the market. At any given period, demand  $D_m$  in market  $m$  is met:

$$\sum Z_{Al} \leq \sum X_{ip}, \quad (7)$$

$$\sum w_{lm} \leq Z_{Al}, \quad (8)$$

$$D_m \leq \sum w_{lm}. \quad (9)$$

## 3. TWO-OBJECTIVE OPTIMIZATION

To solve the SCN problem, Pokharel put emphasis on the objectives of the interactive system. In this method, the non-dominated solution is calculated by giving some amount to an objective function by a decision maker and by using Linear programming.

In the weight method, the objective function  $f_1(x)$  is given the weight  $w$  and  $f_2(x)$  is given the weight  $(1 - w)$ . Then, a unique objective function is minimized:

$$F(x) = wf_1(x) + (1-w)f_2(x). \quad (10)$$

In the proposed solution procedure, a unique objective function  $F(x)$  is minimized with the simplex method. The simplex tableau of two objectives is shown in Table 1.

Table 1: Simplex tableau of two objectives

$f_1$	$f_2$	$x_1$	$x_2$	...	$x_n$	$b$
1	0	$v_{11}$	$v_{12}$	...	$v_{1n}$	$z_1$
0	1	$v_{21}$	$v_{22}$	...	$v_{2n}$	$z_2$
		$v_{31}$	$v_{32}$	...	$v_{3n}$	$b_1$
		:	:	:	:	:
		$v_{k1}$	$v_{k2}$	...	$v_{kn}$	$b_k$

In Table 1,  $v_{ij}$  shows the factor of objective function or constraint equation. First, it considers obtaining the corner point of the non-dominated solution set. If  $f_1(x)$  is optimized using the simplex tableau, then the optimal solution of the weight  $w = 1$  can be found. The simplex tableau which optimized  $f_1(x)$  is extended as follows: the first row of the table shows weight  $w$  and the second row shows the weight sum  $F(x)$ .

Table 2: Extended simplex tableau of two objectives (optimized  $f_1(x)$ ):  $w = 1$ )

$w$	$F$	$f_1$	$f_2$	$x_1$	$x_2$	...	$x_n$	$b$
	1	0	0	$v_{11}^*$	$v_{12}^*$	...	$v_{1n}^*$	$z_1^*$
1	0	1	0	$v_{11}^*$	$v_{12}^*$	...	$v_{1n}^*$	$z_1^*$
0	0	0	1	$v_{21}^*$	$v_{22}^*$	...	$v_{2n}^*$	$z_2^*$
				$v_{31}^*$	$v_{32}^*$	...	$v_{3n}^*$	$b_1^*$
				:	:	:	:	:
				$v_{k1}^*$	$v_{k2}^*$	...	$v_{kn}^*$	$b_k^*$

For Table 2 to show the result of  $w = 1$ , the factors of  $F(x)$  and  $f_1(x)$  must be equivalent. This indicates that all the factors of  $F(x)$  and  $f_1(x)$  are non-negative values. However, if a negative value is included in the factor of  $f_2(x)$ , then the value of  $f_2(x)$  is improvable. Table 3 shows part of a simplex tableau which is optimized for  $f_1(x)$ . Table 3 only shows the sign of the factor of the objective function. In the  $x_2$  row, the factor of  $F(x)$  and  $f_1(x)$  becomes 0; however, that of  $f_2(x)$  is negative. In this case, the value of  $f_2(x)$  can be made to improve without changing the value of  $f_1(x)$ . To obtain the Pareto optimal solution of  $w = 1$ , an improvement of  $f_2(x)$  is needed (Table 4).

Table 3: Simplex tableau which does not become a Pareto optimal solution ( $w = 1$ )

$w$	$F$	$f_1$	$f_2$	$x_1$	$x_2$	...	$x_n$	$b$
	1	0	0	+	0	...	+	$z_1^*$
1	0	1	0	+	0	...	+	$z_1^*$
0	0	0	1	-	-	...	+	$z_2^*$

Table 4: Simplex tableau which becomes a Pareto optimal solution ( $w = 1$ )

$w$	$F$	$f_1$	$f_2$	$x_1$	$x_2$	...	$x_n$	$b$
	1	0	0	+	0	...	+	$z_1^*$
1	0	1	0	+	0	...	+	$z_1^*$
0	0	0	1	-	0	...	+	$z_2^*$

Next, this study considers obtaining the non-dominated solution, which neighbours the corner point of the non-dominated solution set. The essence of the proposed solution procedure is how to define the values of weight  $w$  to derive



the set of non-dominated solutions. These values are sequentially determined with the result for the LP problem, such that each weight value gives a different non-dominated solution. Therefore, the number of weights is the same as that of different non-dominated solutions. In the simplex operations, two objective functions,  $f_1(x)$  and  $f_2(x)$ , are included in the simplex tableau. Consequently, it has the same elementary row operations as on other rows, which are performed on two objective functions. When we get the non-dominated solution for the LP problem LP ( $w_m$ ) with weight  $w_m$  from the resulting simplex tableau, we can find the next value of weight  $w_{m+1}$  for the next non-dominated solution.

The weight determination method for finding the neighbouring non-dominated solution is explained using the example from Table 4. In the  $x_n$  row, the factors of  $f_1(x)$  and  $f_2(x)$  have become positive. In this case, the factor of  $F(x)$  takes a positive value without depending on the value of weight. This shows that  $F(x)$  does not improve even if it adds on the basis of  $x_n$ . On the other hand, since the  $x_1$  row differs in the factors of  $f_1(x)$  and  $f_2(x)$ , the weight from which the factor of  $F(x)$  becomes negative exists. If the factor of  $F(x)$  becomes negative in a certain weight then  $F(x)$  can be improved by adding on the basis of the variable and the new non-dominated solution can be found. In this research, the weight used by the next LP problem is determined using the following equation:

$$w_{m+1}^j v_{1j}^* + (1 - w_{m+1}^j) v_{2j}^* = 0, \quad (11)$$

$$\text{subject to } 0 \leq w_{m+1}^j \leq 1, (j = 1, \dots, n).$$

That is, the weight nearest to  $w_m$  becomes  $w_{m+1}$ .

#### 4. MODEL IMPLEMENTATION

The proposed method is performed using Pokharel's numerical example. Assembly and distribution of a product with four unique models ( $p = 4$ ) is considered. It is assumed that suppliers 1–4 can supply module 1, 5–8 can supply module 2, suppliers 9–12 supply module 3 and suppliers 13–17 can supply module 4. These modules are assembled by one assembler and sent to a customer through six distributors and four retailers.

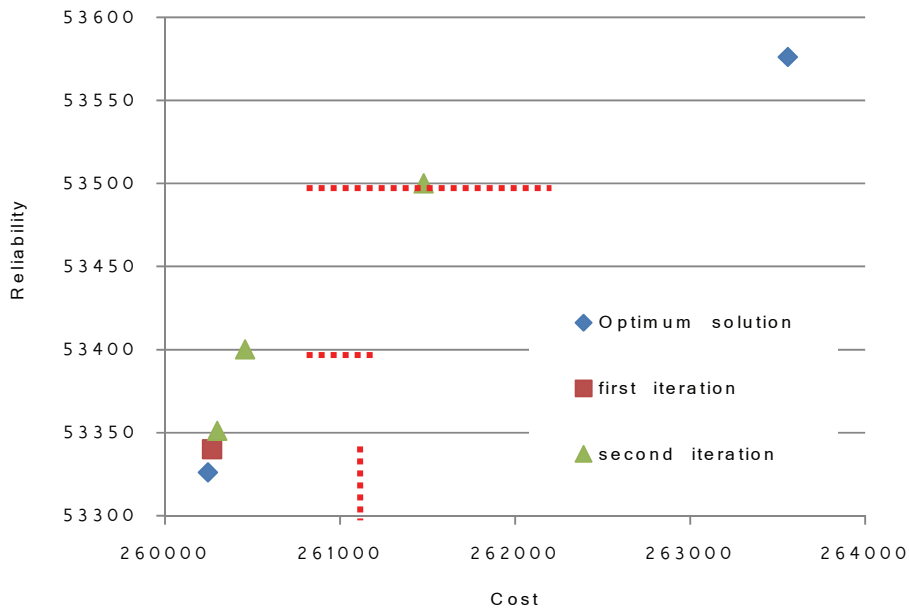


Fig. 2: Allocation values in first and second iterations of the STEP method

Fig. 2 shows the results for the STEP method. In the STEP method, weight is calculated as (0.91; 0.09) on the basis of the optimum value of cost and reliability. In this case, it is noted that {260,270; 53,340} defines the first iteration's solution. For the second iteration in the STEP method, decision makers may want to choose a higher reliability composite number or lower cost from that obtained in the first iteration. Fig. 2 shows the results in a case where the reliability composite is fixed at 53,400 or 53,500 and cost is fixed at 260,300. Therefore, if the decision-making environment changes, the choice of the solutions can also change along with the decision makers. However, if all the non-dominated solutions can be found from the beginning, then the decision maker can simultaneously change a new solution with an environmental change.

Fig. 3 shows the result when the proposed Pareto optimization procedure is performed. For Pokharel's example, there are fourteen non-dominated SCN solutions. The proposed Pareto optimization procedure can obtain all the non-dominated SCN solutions without skipping or overlapping a solution.

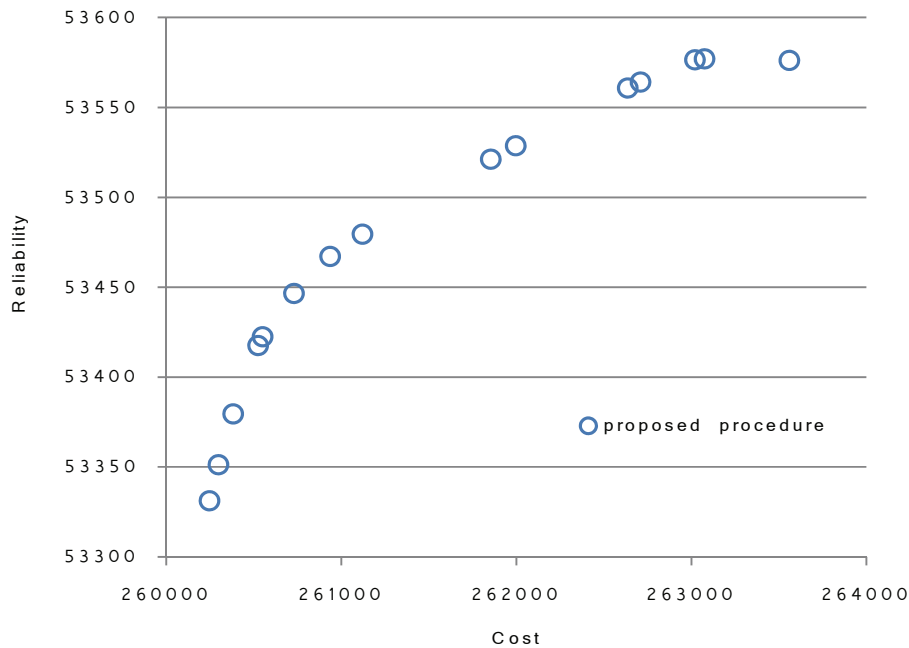


Fig. 3: Allocation values of proposed Pareto optimization procedure

## 5. CONCLUSION

This research developed a solution procedure for obtaining Pareto optimal solutions for Pokharel's SCN model. The proposed Pareto optimization procedure can quickly generate a set of non-dominated solutions. From the set of non-dominated solutions, decision makers can easily select a SCN depending on their preference of objectives.

A two-objective linear programming problem was treated in this study. However, the extension to the multi-objective linear programming problem is possible for the proposed Pareto optimization procedure.

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# **SUPPLY CHAIN RESILIENCE OF KYRGYZ TEXTILE COMPANIES IN REGIONAL INTERNATIONAL TRADE INTEGRATION**

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## **ABSTRACT:**

The transitional period of the Kyrgyz economy from planned to free market economy modified the structure of the textile sector. The state owned big textile producers were fragmented into small sized private apparel manufacturers. The main success factor of transformation was the international trade regulation and international textile market conjuncture. Latest regionalization processes of Kyrgyz apparel exporting countries modify the existing competitive advantage of Kyrgyz apparel cluster and obligate to redesign the supply chain in order to withstand the disruption. The main purpose of the paper is to analyze the success factors of resilient supply chain during transitional period and the possibility of transferring from the global to a regional supply chain as the main resilience factor of Kyrgyz apparel companies.

**Key words:** organizational resilience; regional supply chain; transitional economy; Customs Union

## **1. Introduction**

After fast international trade integration Kyrgyzstan's customs barriers were facilitated for importation, including textile fabrics and garments. As the first former Soviet country Kyrgyzstan joined the World Trade Organization (WTO) in 1998. By the obligations taken during accession to the WTO Kyrgyzstan should have customs duties at a level below 10%. Previously, the Kyrgyz customs duties for importation of textile productions were established at 10% in 1996, so integration into the WTO had no big influence on international trade of the Kyrgyz textile production. But in 2003 the 10% importation customs duty was changed to a weight-based system of taxes on importation by a decree of the Kyrgyz Government to boost production of textile sewing companies by providing cheap raw materials. The decree had a double effect on the Kyrgyz textiles sector in long term and short term perspectives. In the short term perspective, saturation of imported cheap fabrics, threads and accessories on internal open market allowed the development of small sewing companies. The flip side was the inability of upstream level producers to compete with cheap and fashionable fabrics on the internal market, hence the bankruptcy of most of them. Preferences for production of countries in the Commonwealth of Independent States (CIS) on Russian and Kazakh markets by the CIS free trade agreement allowed Kyrgyz garments to be competitive. On one hand the CIS free trade agreement implies removing any duties except the VAT from other CIS countries, and on the other hand the Russian and Kazakh markets were protecting their

internal textile sector by high importation taxes for third countries, including China. The result was a raise of apparel production volume 30 times since 1998, where 90% of the production goes for exportation, mainly to Russia and Kazakhstan.

This favorable international trade conjuncture beside the development of the sewing sector also generated re-exportation of Chinese textile productions with the label "made in Kyrgyzstan". Kyrgyzstan, in the form of an immense open air market place, became an international trade hub for neighbor countries, where foreign private retailers could make wholesale purchases. The bypass of Russian and Kazakh customs regulations in force, better protection of internal markets of these countries, and the ambition of the Russian governance to regain its geopolitical role in post-Soviet countries ended with the creation of the Customs Union (CU) between Russia, Kazakhstan and Belarus in 2010. The idea is to promote intra-CU trade and production by making an economic free trade area with common external borders. Kyrgyzstan is still benefiting from the CIS countries' free trade agreement, but the barriers are getting a non-tariff form as import procedural hurdles. These regionalization and protectionism measures will perturb Kyrgyz textile exportation in the short term. In April 2011 during his official visit to Russia the president of the Kyrgyz Republic Almaz Atambaev expressed political willingness to integrate into the Customs Union by the end of 2013. Medium and long term effects on Kyrgyz economy of a regionalization would be difficult to predict at this stage. Even the Kazakh economy is rebounding from initial inflation caused by higher importation rates. The big challenge for the Kyrgyz fragile economy with a low level of internal production is to be resilient enough for first time inflation.

Accession to the CU presumes annulation of importation facilities for raw materials from countries outside the CU. Nowadays textile importation from China represents 80% of all textile importation in Kyrgyzstan. Loss of cheap raw material sourcing makes it necessary to redesign the actual supply chain to keep the fragile Kyrgyz apparel sector resilient. The main issue of Kyrgyz textile sector on multilateral negotiations about integration in the CU would be terms of temporary importation facilities accorded for textile raw materials trade. The facility transitional period of integration in the CU would be assessed as a function of Kyrgyz apparel companies' resilience.

The main purpose of the article is to provide a basis for possible redesigning of the Kyrgyz textile supply chain in changing international trade regulation context. The main questions are as follows. What are the resilience factors of existing Kyrgyz textile supply chain? What are the conditions of developing a competitive advantage of textile companies? What are changes in supply chain to be undertaken for Kyrgyz apparel organizational resilience? Through understanding the actual situation of Kyrgyz apparel industry in the first part we will analyze the effects of the regionalization process on textile sector in the second part.

## 2. **Frame of reference**

### **2.1 Textile production transformation during the transitional economy**

After the collapse of Soviet Union in 1991 the independent Kyrgyz government chose shock therapy as a way of fast transition from planned to free market economy. Fast economic reform and recovery were advised by the International Monetary Fund. Inspired by the example of Poland's reforms and based on the theory of shock therapy of Jeffery Sachs, the Kyrgyz government began vast privatization of state-owned textile companies. International trade liberalization saturated the domestic market with cheap, fashionable but low quality textile production from west China. New owners of huge textile companies with obsolete production technology, without basic knowledge of management in a market

economy, could not complete the challenge to compete with imported goods in the domestic market. The Kyrgyz economy is still in transitional progress as the transformation period for different sectors can take at least 20 to 30 years (Samson, 2002).

A favorable environment for apparel business startup was created in the early 2000s, due to international apparel market conjuncture, state taxation system, low input production factors and geographical position. Kyrgyz textile economy took part in the assembly part of the global value chain, using imported Chinese and Turkish fabrics and thread to export garments to the Russian and Kazakh markets. Weight-based customs duties for raw material importation in combination with the CIS free trade agreement let Kyrgyz textile production compete on neighbor countries' markets. Lately the international textile market observes a rise of post-Soviet countries as new actors of the global value chain. South-south trade trends, described by Milberg and Winkler (2010) took place by the development of consumer purchasing capacity of emerging countries as Russia and Kazakhstan. CIS countries tend to deal with each other by the force of established logistical connections, historical preamble and language facilities. Moreover, recent Russian recuperation of geopolitical influence on the Central Asian region by a regionalization process boosts development of the textile sector. Shifted competitiveness in CIS markets by late regionalization and Russian globalization processes obligates to re-estimate the risk management tools. Natural disaster mitigation and operational flexibility purposes underline the importance of diversification of sourcing for organizational resilience to withstand unforeseen crises.

## **2.2 New actors in international textile markets**

The Ricardian theory of international trade and of comparative advantage shows the gain of nation in such trade. The Heckscher-Ohlin international trade model demonstrates that a nation produces goods that use factors of production that are relatively abundant locally. Kyrgyz apparel production with abundant low wage cost and cheap energy input uses factors that enable specialization in CMT and full price for Russian and Kazakh private agents.

Kyrgyz apparel is exported to Russian and Kazakh markets mainly. Official statistic data of Kyrgyz National Statistic Committee shows 95% of garments go to Russia. As textile exportation to Kazakhstan has an informal side, its share is estimated unofficially at 25-30% of whole textile exportation. Kyrgyz textile exportation had a constant rise from 2001 and the actual level is multiplied more than 60 times from 2001. Only 10% of domestic textile production is consumed inside the country. High dependency on sales markets, due to low diversification and creation of the CU in Kyrgyz exportation markets with high protectionist measures will redesign the actual supply chain of the Kyrgyz apparel production to avoid failure, hence to build its organizational resilience.

## **2.3 Redesigning the supply chain for organizational resilience**

Resilience of Kyrgyz textile companies is extremely important in the context of a changing environment. Organizational resilience is defined as the ability of a company to bounce back from disturbances (Sheffi, 2005). This is a challenge for Kyrgyz companies after the shock of international trade regulation modifications. After integration in the CU, the external borders of the CU will be extended to the Kyrgyz border by aligning international trade policy and establishing common importation tariffs for all countries. Hence the Kyrgyz apparel comparative advantage mostly gained by abundance of imported raw material on the local market, due to Kyrgyz international trade policy will be under question. The disturbance of the supply chain caused by regionalization processes will modify the sourcing matrix of Kyrgyz apparel producers. One of the resilience essentials for SME, developed by Pal et al. (2013) in an empirical study of Swedish textile SME, is relational networks. Close relationship with upstream and downstream

partners and external support are main key factors of supply chain reinforcement. Regional integration of Kyrgyzstan and globalization of Russian market after joining the WTO re-estimate comparative advantages of Kyrgyz apparel on CU markets.

Sheffi and Rice (2005) define resilience as the ability of a company to bounce back from a disturbance before the crisis level is reached. Theoretically one has to seek an answer to the question: what time can a company employ to recover before reaching a crisis level to be considered as resilient? Financial liabilities of bank loans or stakeholders' interest and commercial liabilities of delivering manufacturing orders have a limited period of time during which a company can demonstrate its operational and functional efficiency. The adaptive capacity of Kyrgyz textile companies has to be tested within a certain time, by development of a new raw material sourcing map.

In designing resilient supply chains Christopher and Peck (2004) recommend to keep several options of sourcing, despite the higher price of alternative sourcing, as it may provide an opportunity to reduce the impact of disruption. Risk management practices advice to reduce geographical density of the sourcing map by regions to avoid shortage, if natural, political, social or economic disruptions touch a certain sourcing region. These resilience time and raw material sourcing diversification issues will be analyzed in the last section of the paper.

The delocalization of Western production to low wage cost Southern countries was possible due to technology development. The movement of production regions, due to alignment of input factors, is shown in a study for the World Bank (Frederick & Gereffi 2009). After a wage cost increase in Pacific Asian countries new producers appeared, as China in the 1980s. The globalization process and international free trade have features to align the input factors of countries, as developed by Samuelson (1949). Former apparel production countries delocalize the assembly part of production and specialize at the upstream level that has more capital density. The recent shifting period describes the specialization of China in production of fabrics, and new actors as Bangladesh propose their lower wage cost for assembly part that has higher labor density. These new actors are forced to work in a triangle manufacturing scheme (Gereffi & Fernandez-Stark 2011) that supposes delegation to existing Chinese partners to find low wage cost country producers without doing contracting directly from Western countries. Due to the geographical position and coming regional integration of Kyrgyzstan into the Customs Union, Kyrgyz apparel production can represent an extremely high interest for Western brands that foresee expansion to the Russian market, which is under constant growth. The main challenge for Kyrgyz authorities would be to handle the lowest wage cost attractiveness in free labor movement and inflation due to adhesion to CU.

### 3. **Actual situation of Kyrgyz textile and apparel production**

The transformation of planned to free market economy caused severe disturbances for the whole domestic production in Kyrgyzstan in the early 90s. The textile production value chain had internal autonomy with great interaction with other Soviet economies. The shock therapy of economic transformation, undertaken by the Kyrgyz government, modified the structure of the textile value chain. Liberalization of economic activities, market conjuncture and textile sector support policy of the Kyrgyz government contributed to the discrepancies of the textile value chain parts that were developing independently from each other.

#### **3.1 Production of fabrics collapse**

During Soviet time the textile sector was dominated to 80% by fabric and thread production. The agricultural orientation of the regional economy was suitable for cotton, woolen and silk fabrics and thread production. Most companies had

modernized their machinery in the 80s and possessed modern production lines. The first steps in economic transformation were marked by fast privatization of state-owned textile companies. New textile managers had low understanding in free market operations. As they had big production lines with several thousands employees in each company, production capacity was underused that did not permit an economy of scale. Loss of outlets, and costly production of natural consistent and out of fashion fabrics did not meet enough demand on the domestic market. Fast liberalization of international trade and the geographical proximity to China had great influence on the Kyrgyz textile sector during the economic transformation period. After the weight-based customs duties were introduced, the internal market was saturated by cheap and fashionable imported raw material that smashed vulnerable upstream level production companies. The Kyrgyz government had unsynchronized initiatives to rescue textile producers by investment in foreign currency. National currency devaluation, debt burden, agricultural reorientation and high competitiveness of Chinese synthetic, fashionable and cheap fabric and thread made the fragile sector of upstream textile production collapse.

### **3.2 Sustainability of knitting companies**

Knitting companies were more sustainable to changes of market conjuncture. The large state-owned company "Ilbirs" could maintain its production of basic garments that could meet demand in neighbor countries without requiring innovations and designing upgrades. Also the former huge producers could withstand the production decline by diversifying their activity out of their production functions. New knitting companies in form of SME appeared lately, that still target the old-age customer category of countries that has penury of modern garments due to local importation policy. One can summarize that knitting companies could find market niches of production with natural components that represented low interest for Chinese competitors. But still the production is limited by highly seasonable specificity of production and lack of innovation in the sector.

### **3.3 Fast development of sewing companies**

The dilemma of international trade liberalization in the medium term is the importation trade facilitation that developed the Kyrgyz apparel sector. Liabilities of Kyrgyzstan during membership into WTO of maximal 10% of tariff for all importations of textile were changed by weight based importation ultimate tariff of US\$ 0.15 per kilogram. International trade regulation facilities developed several open air markets next to Bishkek that later became cluster concentration with 98% of apparel production. Garment manufacturers could find Chinese and Turkish apparel as well as cheap fabrics and accessories on nearby sourcing that decreased lead time of Russian and Kazakh private agents' orders. Other favorable factors for fast development of sewing sector are low input cost in cheap electricity, local rent and wage as well as informal doing business possibility and other sector high investment request.

High labor density sector with low capital investment represented big interest as best business startup option in context of low level of legal administrative procedure requirements. Most of sewing companies rose in illegal economy using old machinery and locals of privatized soviet textile companies. With need of legal certification requirement for exportation to Russia and governmental facilitation of taxation in 2004 most of SME in textile sector passed for legal doing business model. The official statistic of raise in 2004-06 by 3 times of textile production can be explained by this phenomenon.

Due to governmental policy of SME development stimulation policy small companies till 30 employees are free to establish juridical entity and work as individual entrepreneurs. They benefit more with social security fee and tax facilities than big textile producers. De facto the structure of Kyrgyz apparel



sector that is 60% of whole textile sector is represented by small sized companies. Small companies' flexibility by nature of SME's is the main resilient quality. During electricity shortage in winter 2009 and national border closes in spring 2010 small size of companies let them withstand the disturbances. Flexibility in production changes and horizontal integration with other apparel SME let them share production capacities and orders to align order fluctuation by all SME. Flexibility of SME would be also resilience quality in changing international trade regulation.

#### 4. **New supply chain design in the regionalization trend**

During the Soviet period Kyrgyz economy was based on textile upstream production, including the whole supply chain inside the country. After liberalization of international trade the weak value chain was broken. Huge factories for fabrics and thread production could not compete with cheap Chinese production. Hence due to advantages of international trade regulations and low entry barriers Kyrgyz textile industry took part in the global value chain with deep specialization in the assembly part with development of sewing subsector in the early 2000s.

Frederick and Gereffi (2009) conclude that the recent trend of international trade in textiles has two shifts: initiators of trade actions shift from developed to developing countries and so protection of textile industry rather than apparel. Since the end of quota limitation of the Multi Fiber Arrangement in 2005 China has raised its market share in the global textile and apparel market. Some countries have high dependency on Chinese apparel as well as textiles. The Kyrgyz apparel cluster is extremely dependent on Chinese raw material sourcing. Domestic production of fabrics and threads will be difficult by reason of facilitated importation duties of Chinese fabrics as well as high Chinese subsidies on textile sector. China implemented a three-year stimulus package for its textile and apparel sector in 2009. Most of investigations within the WTO on antidumping and countervailing duty actions are made on China.

Kyrgyz textile companies are represented as a mix of assembly and full package combinations. But most of them are SME, having less than 30 employees and restricted by production capacity to work directly with agents and retailers of the Russian market. For Kyrgyz companies it is essential to develop an upgrade to pass from assembly only to full package and spread network with Western retailers and marketers, as full package represents a higher value. Possible advantages of this scheme are low input costs, preferential regulation of market, geographical and logistic ease, and linguistic and cultural issues. This scenario is possible in the long term perspective if Kyrgyz apparel industry can withstand the recent regionalization process of outlet countries in the CU by modification of the existing supply chain.

#### **4.1 Analysis of international trade regulations in the textile sector before entering the Customs Union**

Liabilities of Kyrgyzstan assumed during the membership in WTO in 1998 were to maintain the average of importation tariffs at a level of 5.6%. After regionalization Kyrgyzstan will assume the average level of importation rate of the CU at 10.1%. A comparison of liabilities in the WTO and CU memberships (Table 1) demonstrates the raise of tariff barriers for importation of fabrics, threads and apparel accessories after membership in the CU. Actual textile sector importation facilities by the method of weight-based tariffs, at USD 0.27 per kg, give wide margins for sourcing cheap raw materials. Due to that, big open markets were established next to the country's capital where most apparel manufacturers are concentrated. Some of these open air markets are specialized in trading of imported textile raw material from different countries. Through better import tariffs the open air markets became the hub of textile sourcing for neighbor countries as well as domestic producers. For local garment

manufacturers the presence of such markets is a luxury of nearby sourcing to decrease their lead time. Direct cooperation with Chinese and Turkish fabric and thread producers is difficult, due to small-scale purchasing by Kyrgyz sewing SMEs. The modification of these open air market actors' profitability, due to CU restriction of re-exportation, will decrease the size of importation of raw materials or increase their margin and constrict those markets. SMEs with limited production capacity will have the challenge to increase their orders to be able to work directly with adequate raw material producers.

Table 1. Tariff rates of Kyrgyzstan

Heading	Current rate	Liabilities of KR under WTO	Rates of CU
Cotton fabrics	0 - 10%	5 - 10%	5 - 15%
Cotton threads	10%	10%	15%
Synthetic fabrics	0 - 10%	5 -10%	5 - 10%
Synthetic threads	0	5%	5-10%
Apparel accessories	10%	10%	15%
Apparel	10-12%	10-12%	10%, not less than 3-5 euro per kg
Sewing machines	0-10%	10%	0

*Source: Sectorial analysis of textile and apparel production of the Kyrgyz Republic, 2012*

Tariff rates for most exportation to CIS countries are based on the agreement of free trade of CIS countries signed in April 1994 and updated in October 2011. This agreement is a basic level of regional integration that does not mean aligning trade policy of countries and does not exclude bilateral tariff modification of trading partners on different goods. This agreement can be applied only for goods that have more than 30% value added in the exporting country to exclude re-exportation of goods. Certified laboratories for estimation of the level of added value are located in CU member countries, where only the methods of analysis can differ. The level of material and components used to create final products is arguable and any transparent standardization will have the purpose to delimit trade procedures and import barriers of the CU. In any case this agreement, that stimulates Kyrgyz apparel production, contradicts the CU principles and would expire by the political decision of the CU members. In order to build a resilient supply chain Kyrgyz textile sector has to redesign its sourcing matrix by passing from a global to a regional supply chain.

#### **4.2 Modified international trade context after creation of the Customs Union**

The CU is in effect between Russia, Belarus and Kazakhstan since June 2010 and represents an upgraded form of the excited Eurasian Economic Community between Belarus, Kazakhstan, Kyrgyzstan, the Russian Federation and Tajikistan established after signing the agreement in 1995 and reorganized as an international organization in 2000. The new format of regionalization has developed for the purpose of liberalization of financial and commercial movements between the member countries. On the example of the European Union the CU aims at creation of a supranational organism, regulating distribution of importation taxes between members, aligning the external trade policy, deleting customs borders between member countries and establishing a common external border. The main purpose of the CU is development of economies by a reduction of lead time by a factor four, due to absence of physical customs

borders, and development of intraregional trade for stimulation of economic growth in a long term perspective.

Kyrgyzstan's strategic trade partners are located in the region. Shares of international trade with the CU countries are 42,7% (Russia 27,6%; Kazakhstan 12,7%; Belarus 2,4%). While the main exportation of Kyrgyzstan is gold with 42%, exportation to these countries is diversified. Kyrgyz textile exportation goes 90% to Russia and Kazakhstan in nearly equal shares, slightly more to Kazakhstan.

Kyrgyz textile exportation had severe disturbances after the setting up of external borders of the CU in 2011. The first impact was a restriction of livestock production, and raised difficulties of frontier trade of all other goods, due to tightening of certification procedures. In a longer term perspective Kyrgyz traders expect tightening of exportation to the territory of the CU by willingness to reduce re-exportation of Chinese goods. Also the regulations and niches to export goods, especially to Kazakhstan, are very vulnerable. The authority of the CU can any time change importation regulations unilaterally.

The Kyrgyz government took the decision to begin the process of entering the CU during its session in April 2011. In October 2011 an international commission was created to facilitate the integration processes to align Kyrgyz legislation to CU regulations, discuss the timing and mapping of entering, and present a decision by December 2013. The foreseen time of Kyrgyzstan entering the CU is January 1, 2015.<sup>9</sup> At this stage the main stake for the Kyrgyz side is to protect vulnerable production by negotiating a transitional period, during which low tariffs would be applied for consumer goods importation to limit inflation in the short term and to ensure business continuity of production. The main issue is the textile sector protection, where it is specialized in assembling parts with importation of raw materials from abroad of the CU territory.

Negotiations of entering the CU will agree on a facilitated period for Kyrgyzstan for trading of sensible goods with third countries. The textile sector, being based on favorable conjunctures of international trade, could show achievements but has to be protected by the government at the first stage of the regionalization process. As almost 95% of raw materials are imported for correct operation of the sewing subsector, the Kyrgyz government is including the sector in the negotiation of vulnerable points and the bargaining period, during which fabrics and accessories would be imported from outside the CU with lower customs duties.

#### **4.3 Resilience time to convert global to regional value chain**

For accession to the CU the Kyrgyz government negotiates the facility period, during which importation tariffs can undertake a light raise and at the same price decrease the profit margin of apparel manufacturers or seek the competitive advantages. Such a period was agreed for Belarus and Kazakhstan for more than 400 sensible items to have minimal unfavorable impact on national production. The President of the Kyrgyz Republic expressed that Kyrgyz authorities hope to have the same facility condition of membership as it was initially for Belarus and Kazakhstan. This period of importation facilities for textile raw material will be the period of time, during which Kyrgyz apparel firms have to redesign their sourcing geography.

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<sup>9</sup> Speech of Valeriy Subbotin, Deputy Director of the Department of sanitary, phyto-sanitary and veterinary measures of Eurasian Economic Commission, roundtable on integration of Kyrgyzstan in the CU, 6 March, 2013

Kyrgyz apparel SMEs have to diversify raw material sourcing in CU members as a complementary sourcing until the facility period ends. This period has to serve for better establishment of interaction with new suppliers and to diversify their amount. After the end of the facility period, new suppliers would substitute of third countries sourcing out of CU that the Kyrgyz textile sector actually benefits from.

Due to gradual transition of Belarus, huge governmental subvention and protectionist international trade regulations in Russia and Belarus they could manage to preserve their capacities in fabric and thread production. Russia was the fourth country in the world in production of fabrics in 1995. Wage cost being highest in the region it gives a niche for development of a regional supply chain with apparel manufacturing in Kyrgyzstan. Russian fabric production is to 70% a production of cotton-based natural fabrics. Use of this fabric can also upgrade the quality of Kyrgyz apparel companies.

Sheffi and Rice (2005) divide the time of resilience into 8 stages. The first part is the reparation period, that is before the disruptive event happens. Russian authorities made a plan to finalize the roadmap of accession of Kyrgyzstan to the CU till the end of 2013, in order to finalize the adhesion processes by the end of 2014. This period is the preparation stage of disruption. More studies on the impact of disruption and preparation of proactive action, especially in redesigning the supply chain in the way that a global value chain would be complemented by a regional value chain, will define the depth of decline of textile companies and the apparel cluster in general.

Present logistic communication of Kyrgyzstan is the heritage of the Soviet logistic network with a railway impasse that was not modified. Railway communication is developed only in north of the country, where all apparel production is concentrated. The absence of sea port access in the country dedicates the greatest role to railway communication with other CIS countries for textile chain redesign.

## 5. **Conclusion**

The supply chain has to be reviewed regularly in a changing environment to safeguard competitiveness, business continuity and organizational resilience. International integration processes have a huge influence on production that can redesign the existing supply chain completely. The resilience of companies can be measured by their capacity to adapt to the changing environment and to redesign their supply chain by enlarging their business network.

Kyrgyz textile companies had substantial development during the Soviet Union. The period of free market construction redesigned existing supply chains of the textile companies. Due to international market conjuncture the structure of the whole textile sector was modified: Most of the fabric producers went bankrupt and large state-owned apparel companies fragmented into private textile SME.

One of the success factors of the Kyrgyz textile SME development was the favorable international trade regulation and the geographical location making Kyrgyzstan an international trade hub for neighbor countries. The actual supply chain of Kyrgyz textile SMEs relies on binding globally integrated world fabric and textile accessories producer countries like China and Turkey with regionally protectionist CIS countries by specialization on apparel manufacturing.

After membership of Russia in the WTO and creation of a regional free trade zone, viz. the Customs Union between Russia, Kazakhstan and Belarus, the existing competitive advantage of the Kyrgyz textile sector is under question. The latest modification of international trade regulations of trading countries re-estimates the competitive advantage and organizational resilience. Kyrgyz authorities made the decision to integrate into the CU from 2014. The import

facilitation for textile raw materials will be substituted by the common importation policy of the CU. Hence the comparative advantage of the apparel cluster will be lost. The main issue of organizational resilience for Kyrgyz apparel manufacturers is their ability to adapt in international trade integration modification by orienting global to regional sourcing within the Customs Union.

Time of resilience in this perspective for the Kyrgyz apparel sector is the period of facilitated sourcing of raw materials, bargaining now within international negotiations with the CU members. During that period textile companies that are very dependent on sourcing have to diversify raw material sourcing within the CU with new complementary partners. After the end of the facilitation period new sourcing partners would amortize the shock of raw material penury on internal market and change the status from complementary to substitution sourcing.

Further research should investigate on detailed production capacity of the textile upstream producers of the CU members. Intraregional apparel specialization of Kyrgyz manufacturers is possible due to the lowest input factors in the region. The main issue is to conserve the low wage cost advantage in free movement of labor in the CU.

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# **RISK RESILIENCE IN SUPPLY CHAINS IN THAILAND**

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## **ABSTRACT**

### **Purpose of this paper**

This research paper explores the impact of a recent calamity and an imminent challenge to company supply chains in Thailand. Foreign firms operate alongside local firms (often foreign-local partnerships), whose supply chains cross boundaries and oceans. Little is published in English about these companies, yet their handling of problems is relevant to a wider world. Recent experiences have included disastrous floods in 2011. A Southeast Asian economic community to begin in 2015 is an opportunity and a threat. With increasing complexity and uncertainty, and ferocious national and global competition, resilience is critical to a firm's survival.

### **Methodology**

This paper is based on empirical qualitative research through semi-structured interviews with seven supply chain managers. Limitations include generalisability, within and beyond Thailand, and the other inevitable limitations of qualitative research.

### **Findings**

From the qualitative interviews, a range of adverse effects are described, caused by floods, with significant evidence of resilience, short-term and permanent. Evidence about resilience to cope with the imminence of a free trade area is not so abundant.

### **Value of this paper**

This is the first qualitative empirical research to provide managers, researchers, and the Thai government, with evidence of how firms dealt resiliently (or not) with disastrous floods in 2011, and how they now might better tackle such events. It also provides them with evidence of how resilient (or not) firms might be when entering the turbulence of a new free trade area. This is a rare contemporary insight into supply chain resilience in a vibrant economic region.

### **Practical implications**

The findings contain lots of practical actions of resilience, which could be of use in future crises, especially caused by water. There is great interest by firms and the government in how to prepare for AEC implementation in 2015, as many firms are unsure what to do.

## **1. INTRODUCTION**

Severe floods in Thailand in 2011 revealed the essential role of internal and global supply chains. Thailand is an attractive factory location for foreign investors, and several industries use Thailand as their production hub for the region or even wider.

This paper presents empirical data on how some firms dealt with Thailand's worst flooding in 70 years, their resilience then and since. These firms now face an uncertain future challenge from a free trade agreement between ten countries in the Association of South-East Nations (ASEAN): Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. This ASEAN Economic Community (AEC) begins on 31 December 2015. It will create a

single market, free from trade barriers for products and services, with freedom for companies to locate in any of these countries. With public accusations of unpreparedness (the reason for deferring the start date by one year), this research tries to discover how firms can have resilient preparedness.

## **2. LITERATURE REVIEW**

Risk is the probability of experiencing a less-than desirable event that affects one or more parties within a supply chain (Schlege & Trent, 2012). Globalisation and international trade are the key drivers of the complex network of supply chains. When unexpected events occur, such as a tsunami in Japan or floods in Thailand, these trading webs are disrupted. For example, failure to deliver to the customer, is an uncertainty, with several causes including unexpected weather conditions (Ho, Chi, & Tai, 2005).

To manage supply chain vulnerability, firms must plan for resilience and continuity, yet studies show that many organisations have not done this (Christopher & Peck, 2004). Resilience is the ability to recover from disruptions of any type (Schlegel & Trent, 2012). Sheffi (2007) stated that enterprises can create resiliency through 'redundancy' or through 'flexibility'. Creating redundancy (slack resources) provides 'shock absorbers' through extra inventory, spare capacity, redundant suppliers, and product designs that are not dependent on a specific supplier (Tang, 2006). Flexibility is achieved through standardized facilities and processes, interchangeable parts and products, concurrent processes, postponement, alignment of procurement strategy with supplier relationships, and collaboration (Sheffi, 2007). Chongvilaivan (2012) warned that redundancy through extra inventory and suppliers could be prohibitively costly. He also found that creating flexibility through information exchange and collaboration with trading partners is crucial to resilience against high-impact low-probability shocks such as floods.

Resilience implies flexibility and agility: its implications extend beyond process redesign to fundamental decisions of sourcing and the establishment of more collaborative supply chain relationships (Christopher & Peck, 2004). Interestingly, Waters (2011) combines the methods suggested for redundancy and flexibility (Sheffi, 2007; Tang, 2006) and calls them the ways of increasing agility (such as spare capacity, backup systems, stocks of finished goods, holding cash reserves, postponement, and short lead times).

Regarding the AEC risks, Boon-itt and Paul (2006) explored competitor uncertainty. They defined it as unpredictability of competitors' actions regarding marketing promotions, and new products.

## **3. CHALLENGES IN THE PAST (FLOOD) AND THE FUTURE (AEC)**

The World Bank (2012) estimated that the Thai flood in 2011 cost USD46.5 billion in economic losses, making it one of the top five costliest recent natural disasters. The floods had a severe impact on the private sector, especially manufacturing, which represents 38.5% of Thailand's GDP and is one of the main drivers of Thailand's exports (World Bank, 2012). The majority of manufacturers (about 70%) are in five flood-affected provinces. Floods affected 7 industrial estates and 66 of 77 provinces.

The floods affected 4,039,459 households and 13,425,869 people. 2,329 houses were completely destroyed, while 96,833 houses were partially damaged. The death toll was 657 people. Unemployment followed due to the closure of many factories. It was feared that the national economy was threatened through reduced investor confidence, which could lead to more unemployment (Thailand Integrated Water Resource Management, 2012). Enterprises faced serious challenges to survive such an unexpected disaster.

The ASEAN Economic Community (AEC) in 2015, aims to create a competitive group of ten neighbouring countries in a single market and production base, with the free flow of goods, services, investment, skilled labor, and capital. Its population will be 583 million, with a combined GDP of USD1,275 billion (Department of Trade Negotiation, 2009). The imminent turbulence of this change presents risks of both opportunities and threats. These ten nations have many differences, in religion, culture, politics, democracy, and economic maturity, which present challenges to both private and public sectors.

For both topics, floods and AEC, the readiness of some enterprises, during the flood and after, and in anticipation of AEC, are investigated in this research. Readiness, then, now and in the future, is an indicator of resilience, both planned and spontaneous.

#### 4. RESEARCH METHODOLOGY

A qualitative approach is used in this research. Therefore, it has nothing to do with numbers and percentages. The aim is to explore empirical evidence, discover themes which could be used in further research, and identify links with the literature.

Semi-structured interviews were conducted with seven managers working for firms affected by the floods. These interviewees were randomly chosen from graduate students in the MSc program in supply chain management at the largest private university in ASEAN, located in Bangkok. Their details are shown in Table 1, below.

Table 1: Company and Interviewee Profile

ID*	Company Type	Job	Foreign
A-Auto	Automotive	Chief engineer: procurement	Japan
B-Tractor	Tractor manufacturer	Engineer	Japan
C-LSP	Logistic service provider	Assistant general manager	Japan
D-Retailer	Retailer	Merchandise planning manager	UK
E-Jeweller	Jeweller	Procurement manager	Austria
F-Electronics	Electronics	Assistant procurement manager	USA
G-Suspension	Suspension manufacturer	Procurement manager	USA

\*This identity will be used to indicate the interviewee quotes later.

#### 5. FINDINGS AND ANALYSIS

Flood resilience is examined first, through statements made by the seven interviewees. To bring some order into the multiplicity of statements, they will be categorised into the three types of resilience from the literature review above. Sheffi (2007) described resilience through 'redundancy' (low-capacity use, spare capacity, extra inventory, extra workers, and multiple suppliers). 'Flexibility' includes standard facilities and processes, interchangeable parts and products, concurrent processes, and alignment with supplier relationships. Resilience through collaboration is achieved through close cooperative supply-chain relationships (Christopher & Peck, 2004).

##### 5.1 Resilience through Redundancy

The interview results disclosed that firms tried to prepare for and create resilience to deal with the water crisis. If threatened by flooding, machines were moved to higher floors. Various means were used to mitigate severity. Short-term action included temporarily shutting down production plants, distribution centres, and offices, and delaying production plans and shipments. This disaster affected long-term strategic plans. Some firms decided to permanently relocate their plants to



non-flooded areas while some permanently moved some production to their businesses in other countries.

#### Shut-downs and move to other locations

By chance, all the firms studied had more than one production plant, distribution centre, or branch, in various locations. When it became urgent, they temporarily moved to non-flooded plants to continue operations. C-LSP stated that during the flooding they moved their HQ, Warehouse and Transport to another province. In 2012, their HQ and some indirect departments moved permanently to a Bangkok southern flood-free suburb. B-Tractor said that they temporary moved all departments, and permanently relocated the production line of the main product to a non-flooded industrial estate.

In finding capacity elsewhere, F-Electronics stated that the firm managed to survive by using capacity elsewhere in the Asia Pacific region (the firm has worldwide locations). The firm reviewed capacity in the Asia region and decided to move some product operations to a plant in China, and sent an engineering team to China to oversee this.

D-Retailer revealed: "Our first affected store was a supermarket. The biggest impact was the Samkhok Distribution Centre (DC), our first DC to be flooded. Its closure led to shortage of grocery products in our stores. Wangnoi DC was the second to be disrupted by floodwater. That affected almost all other products because this was a DC for non-food items. The two other DCs, for fresh food products and express merchandise, were then also disrupted. We had to close 154 stores because the DC had closed. These were mini-stores, of small capacity. Some of our hypermarkets were affected and had to close for 1 or 2 days because they expected to be flooded. They re-opened after they were found to be safe and dry. Our Head office, in Bangkok, was closed for one month, and when affected by flooding had to move temporarily to the National Exhibition Centre."

F-Electronics experienced the impacts: "We temporarily shut down. We suspended operations because of flooding in the surrounding areas of the Industrial Estate. The industrial park was without power and officials ordered an evacuation of the area. The company moved all equipment, raw materials, and finished goods to the second floor."

G-Suspension said: "We experienced a high flood level, interrupting our business and the whole chain. We built barriers to protect manufacturing which was successful. But the area was flooded, so our HQ and manufacturing plant closed for three weeks. Employees were evacuated, and equipment and machines moved to a safe place for six weeks."

E-Jeweller realized that it should not risk putting all the firm's eggs in one basket. 80% of its sales worldwide are products made in Thailand. Before the floods, the company planned to set up a distribution centre in Thailand. After the floods, it decided to set it up in Singapore instead, even though the operating cost is higher. In addition, the company is building a new factory in Vietnam with a similar capacity to Thailand.

#### Sourcing from other countries

D-Retailer said: "Because of stock shortage from local suppliers, we then used suppliers in Hong Kong, Malaysia and Taiwan, for essential basic items which customers desperately wanted. It took a week to deliver to Thailand by plane. The reason for ordering from abroad was quality and certainty because the goods were purchased from qualified manufacturers, and order quantities and delivery were guaranteed."

Changing from single sourcing to multiple sourcing

The Chairman of Toshiba Thailand reported that her firm had ten factories inundated by floods, up to three-metres high. There was a review of overall sourcing strategy. Single sourcing for some parts would have to be changed to multiple sourcing, to reduce the risk of supply shortage from inbound disruptions (Wattanavrangkul, 2012).

## **5.2 Resilience through Flexibility**

The firms studied dealt with the floods through their supply chain flexibility. They switched to other transport, standardized facilities and processes, and set up temporary offices and distribution centres.

Using other transport

In Thailand, trucks (vans, lorries) account for 88% of transportation compared to 2% for rail freight, and 10% for ship freight (Logistics Digest, 2009). D-Retailer revealed that: "...the company used public transport such as train and plane. We used train containers to deliver products to many provinces, on three routes. The goods were prioritized and the most essential items allocated to containers."

Standardised facilities and processes:

Most interviewee firms were able to continue production and operations by moving to non-flooded factories. As their plants and processes are identical, some employees were temporarily transferred, as in the case of E-Jeweller: "After the Ayutthaya factory was closed down, some workers were transferred to our smaller factory at an industrial estate where the company also provided accommodation. Workers who could not manage the move, still received 100% of their salaries. Totally unexpected, employees in Austria generously donated money to their Thai colleagues."

Setting up temporary office or distribution centre

Some firms rented space for temporary offices or DCs. F-Electronics rented a temporary office in a Bangkok hotel, using it for joint recovery planning with its customers.

D-Retailer said: "The biggest impact from flooding was the disabling of four DCs. The first thing was to set up temporary DCs, of two types. The first was to rent a place at the old northern Bangkok airport, but this area too became flooded, so it was moved to the National Exhibition Centre in south Bangkok, and was also used as temporary HQ. We set up five stores to be mother stores, hubs for upcountry distribution. They were provided for suppliers whose warehouse or factory was nearby. Due to limited space and time, these stores were mainly stocked with essential items, such as rice, water, and instant noodle. For non-urgent items they had to look for cooperation from their own suppliers to find ways to deliver goods to stores."

## **5.3 Resilience through Collaboration**

A-Auto said that some suppliers were flooded and could not continue. So, the firm halted production in three plants for five days. Japanese keiretsu, strong partnerships and a web of supply networks provided resilience: "Our firm then ordered parts from Indonesia and Japan instead. But it was not enough for us to fulfil an order from the Middle East. We incurred many backlogs. But the Thai domestic market was not the company's focus as many Thai customers requested a delay in selling them a car in troubled times. Ordering imported engines in big lots from suppliers in Indonesia and Japan by plane lasted only for a short period. But when those new suppliers realized that their local suppliers for small parts could not meet the increased demand, they also stopped delivering to us. So, the production plan was reduced to one shift instead of two. Workers were asked to

be on the production line for six hours, with two hours spent on safety activities. Supplier disruptions lasted a month before all production resumed.”

The experience of D-Retailer was: “Direct delivery to stores was one way to fulfil customer needs, but that needs a lot of cooperation from suppliers because they had to deliver the stocks to stores by themselves. They had to use their own trucks or third party logistics (3PL). However, if the product quantity of each supplier was small or suppliers could not manage such transportation, all orders from those suppliers were consolidated and divided into appropriate regions. Suppliers with better capability were assigned to be representatives to deliver orders or use 3PL. However, it took time to consolidate orders and distribute them to stores, because suppliers themselves were also in trouble and many orders were rejected by 3PL. The delivery flow was not as planned.”

In addition to collaborative relationships with supply chain partners, some firms tried unusual survival resilience by working with a competitor. Such was the case of Big C Supercenter, a leading hypermarket operator, a joint Thai-French venture. As reported by Big C Supply Chain Director, in the floods in 2010 some provinces were devastated, and Big C had difficulty in delivering to the flooded areas as highways were closed. So, they invented ‘co-opetition’, i.e. collaboration with the competition. Big C agreed to share the 3PL, DC and truck loads. Collaboration between competitors is not new, but is rarely seen in Thailand’s retail industry (Chirasawee, 2011).

In the interview, Big C’s supply chain executive referred to this: “A time of crisis forces us to think and act differently. Things which normally would be impossible or unthinkable become possible. Part is a survival instinct and part is the Thai way of helping each other – We are all Thais. Big C’s collaboration with a direct competitor may seem unthinkable – but this was a crisis.”

A-Auto was only indirectly affected, by suppliers’ disruptions. Due to its just-in-time lean manufacturing strategy, the disruptions of the supply networks caused parts shortages, and the assembly line had to stop: “Our suppliers could not operate and supply their parts to us, therefore: 1.No parts were available to manufacture cars, so we had many backlogs for overseas and domestic orders; 2.We shut down three plants during October to plan and solve the problems; 3.Normal roads were cut off, so we couldn’t receive parts on time, which affected production plans; 4.We delayed the production plan and shut down the night shift for two months; 5.We delayed shipments to customers.”

#### **5.4 Present Practice of Risk Identification and Management**

Information was given by the interviewees on what their company now did differently after experiencing floods. For D-Retailer, the most serious issue is about distribution centres. So, it is planning to build more DCs upcountry so that stores which were not flooded would not be affected by flooded DCs. The firm has made a list of essential items necessary in a crisis, and is sourcing goods from more overseas suppliers.

F-Electronics identified two key external risks: natural disaster risks and political risks. The firm has developed a contingency disaster plan after its bad flood experience. The company now has a risk management team to identify all risks and find alternative ways to handle them. It has transferred the disaster risk to insurers who cover flood losses and business interruption losses. For political risks, the interviewee believed that politics contributed to the drawn out (four months) flooding. It seemed that the government did not have an adequate plan to manage the disaster and enhance recovery. Since then, the government has set up a flood protection policy, for instance, early warning systems, preparedness, an emergency response protocol during crises, and flooding

mitigation systems. The government has established two major plans to provide flood protection in both the short-term and long-term: a main flood protection plan with a budget of 100 billion USD, and a national catastrophe insurance fund with a budget of 1.6 billion USD.

G-Suspension disclosed that the firm now manages the risk through a pre-prepared action and protection plan, risk mitigation, and training. B-Tractor said that supply risk is its focus, which is identified and managed according to the location of each supplier (flooded/non-flooded area) and by applying portfolio analysis to different parts in terms of their value potential and risk. E-Jeweller decided that communication from the government to the public was not reliable. The company now spreads its risks through different geographical areas, Vietnam and Singapore, because concentrating 80% of its production base in Thailand is now seen to be too risky.

C-LSP focuses on the natural disaster risk, and has moved its indirect department away from flood areas. Its direct departments (warehouse and transport) have produced a Business Continuity Plan (BCP) and have explained it to employees and customers.

A-Auto said that a flood team was set up during the flood period. Flood risk is now identified by this firm according to 'the water level above Mean Sea Level' (MSL), with corresponding action, including wrapping parts in plastic, and intense monitoring.

### **5.5 Planning Resilience for AEC Implementation**

Implementation of the AEC in 2015 was the second theme of the research interviews. Several interviewees agreed on the risks of increased competition. Some pointed out the human resource risk as a key challenge. One stated that there are no risks.

D-Retailer said: "In my opinion, customers will have more choices, so the competition becomes more intense and there will be discount promotions, which will affect profits. If current local suppliers cannot compete with the entry of new competitors, and they have to close down, my company would have to begin with new suppliers who may not have similar expertise to previous suppliers."

F-Electronics elaborated on the competitive risk and human resource risk:

"Competitors will be able enter AEC more freely to invest in ASEAN. That means more competitors. There is also a manpower risk. In the AEC, human resources will be able to move around the region freely. The key question is how to manage the flow of people in and out of the organization and across borders, and how to adapt people management practices to cope with the changing nature of the workforce."

C-LSP was concerned with internal resources: "Our employees cannot understand the AEC scheme. We are a logistics company and expect a higher frequency of cargo activity. Therefore the HR risk could be a constraint: inefficiency & ineffectiveness could occur. If employees do not understand the AEC scheme, the company may lag behind others in grasping new market opportunities."

B-Tractor expressed his fears about more competition: "Competitors from China will find it easier to enter our market." ASEAN countries have been working on an economic partnership with China, Japan, and Korea, under the labels of ASEAN+3, or EAFTA (East Asia Free Trade Agreement). This group will have 2,068 million population, equivalent to 31% of the world population, with a GDP of USD9,901 billion or 18% of world GDP (Department of Trade Negotiation, 2009).

A positive attitude came from G-Suspension, convinced that: "AEC will help in developing capacity and capability because many investors will be interested in ASEAN. So I expect that we will have a chance to get more suppliers and have the potential to compete in other zones especially in the industrial field."

However, A-auto said: "Most AEC countries have lower wages than Thailand. Investors may relocate their factories to those countries. Our company may have to order parts from those countries instead of from local suppliers. That means higher cost for transportation and shipment. There are differences in both language and nationality. Human Resource Department must employ newcomers from other AEC countries to increase our competitiveness and effectiveness. This means higher employment costs."

### **5.6 How Well Prepared is an Individual Firm for AEC?**

A couple of interviewees said that nothing has yet been prepared for the AEC. The others were aware and have attempted to grasp future opportunities or ward off threats.

A-Auto was definite about its future. It will expand its overseas market. Thailand will be the distribution centre for car sales. It will move some models to be fully manufactured in Indonesia because of its similar infrastructure yet lower cost. Its human resource development will strengthen English language and other skills. Similarly, E-Jeweller said: "We are working to expand a factory in Vietnam and we are learning about Vietnam. We have a logistics hub in Singapore where we know its law and culture. We have a procurement team in Hong Kong, close to the China market."

However, B-Tractor said: "We will create brand loyalty from Thai farmers. Our company is afraid of cheaper products coming in to Thailand, so brand loyalty will help us retain our customers." D-Retailer disclosed that the CEO had answered this kind of question in the firm's half year business review stating that there are no solid plans for AEC but he will keep this issue in mind (he may have been keeping his plans confidential until later).

The interviewee from F-Electronics stated: "Our company needs to prepare and train all employees in the details of AEC. Especially important are import and export regulations. The Human Resource Department has prepared guidance in three key areas. First are customs procedure changes, for expediting customs clearance and release of goods for import. Second, ASEAN operates in an increasingly globalised environment, with interdependent markets and globalized industries. Our company must look beyond the borders of AEC and consider regulations outside the region in forming our policies related to AEC, including the adoption of international best practices and standards in production and distribution, to gain competitive advantage. Lastly, our company is training all employees in, for instance, communication skills, and human capital management."

## **6. DISCUSSION AND CONCLUSIONS**

Empirical evidence has been presented from the seven interviewed managers that there were quick-thinking resilient responses to manage the very serious flood problems. Some were obvious (in hindsight), some were creative, some were temporary and some permanent. These companies did seem to learn from the experience and some are better equipped and organised for the next crisis, especially if it involves water. In qualitative research there are usually surprises. Here, the collaboration between competitors went against all that textbooks and research tell us about the need to be competitive. It was a successful pragmatic temporary solution. Another surprise was the morale-boosting sympathy and

donations from a foreign HQ company. That some firms continued to pay full salaries, even to those unable to work, was remarkable and shows strategic thinking amidst the stresses of a disaster.

The information given about resilience in facing an imminent AEC were less sure, sometimes cautiously defensive, sometimes positively assertive, and sometimes uncertain about what would happen and what to do. Less information was given by the seven managers on this topic. This may be because, unlike floods actually experienced and tangible, the AEC's not-experienced future, and its complexity and uncertainty about what will actually happen, produces confusion, although eighteen months still remain in which to crystallise plans.

Both topics, floods and AEC, have many similarities, especially competitiveness, financial strength, and manpower, in which resilience is needed to survive. Both also affect the national competitiveness of Thailand as a nation. Micro (firms) and macro (government) need each other and are interdependent. Finally a warning, that qualitative findings cannot be generalised or quantified but provide substance which can help future researchers, managers, and ministers.

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## GREEN SUPPLY CHAIN FOR RUBBER TIRE PRODUCT

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### ABSTRACT

**Purpose of this paper** – This paper explores the activities which lead to the 'greenness' of rubber tire supply chain through the study of the entire rubber tire supply chain. The purpose of this study is to propose a 'best practice' for the green rubber tire supply chain and to determine which activities could be improved to reduce the environmental impact of the industry.

**Design/methodology/approach** – This study develops evaluation matrices for a 'greenness' assessment. Evaluation matrices include the activities in the rubber tire supply chain which are defined as green purchasing, green production, green packaging, green transportation & distribution and reverse logistics. Then the experts and executives of rubber industry organisations are asked to determine what the best practices for green supply chain activities would be. After obtaining best practices, a case of rubber tire supply chain is evaluated by the executives and experts applying the matrix and best practice. Later in the study the case companies are analysed to identify the 'hot spot' for 'greenness' improvement.

**Findings** – The current rubber tire supply chain is not yet green. There are activities in the supply chain which need improvement including green procurement, green production and green transportation of the rubber block manufacturer (mid-stream) and rubber tire manufacturer (down-stream). The logistical design practices can be employed to enhance the greenness of rubber tire supply chain, such as transportation and distribution planning, production and inventory planning and others. The evaluation matrices developed in this study are used to evaluate the 'greenness' of the supply chain activities. These evaluation matrices can be extended to application in other rubber product supply chains where activities in the chain are similar.

**Originality/value of paper** – This paper presents guidance for implementation the green supply chain concept to the entire rubber tire supply chain. The evaluation method of each activity along the supply chain as well as the practices for the greenness of each activity is also presented in this study. The green activities in the rubber tire then lead to green rubber tire supply chain and eventually can enhance the green rubber products. Moreover, this paper also highlighted the activities which have high impact to the greenness of the rubber tire supply chain.

**Keywords:** green logistics and supply chain, performance assessment, rubber tire

## **INTRODUCTION**

Rubber tire can be considered an important commodity for automotive industries. The production as well as other logistics activities in rubber tire supply chain typically have impacts on environment. Such impact becomes an important issue in the past few years because of the public concerns in environment. The reduction of logistics activities' impacts on environment is increasingly required (Lau, 2011). The study of green supply chain has been implemented in automotive industry (Olugu, et al., 2010). However, the greenness of rubber tire product which unavoidably affects the greenness of automotive supply chain has not been investigated. As Kangang (2011)'s insertion, the successful of implementation of green supply chain rely on the systematic view of the entire supply chain. Therefore, it is vital to study the greenness of rubber tire supply chain in order to complete the previous study of green automotive supply chain. This study initiated with an objective to investigate the green supply chain of rubber tire industry. The study begins with exploring the structure of rubber tire supply chain consisting of the transportation of latex from farmer, rubber block manufacturer and rubber tire manufacturer, as well as the logistics activities along the chain especially within the rubber block and rubber tire manufacturers. The investigation of green rubber tire supply chain implement the performance matrix developed for this study. The results of investigation are used as a mean to develop 'best practice' for green procurement, green production, green packaging and green distribution and transportation. The rest of the paper is organized as follows. The concept of green supply chain management is reviewed. Then, the rubber tire supply chain is illustrated in both structure and activities in the chain. After that, the development of performance matrix is elaborated. Finally, the result of assessment and the best practice for the green rubber tire supply chain is explained.

## **GREEN SUPPLY CHAIN MANAGEMENT**

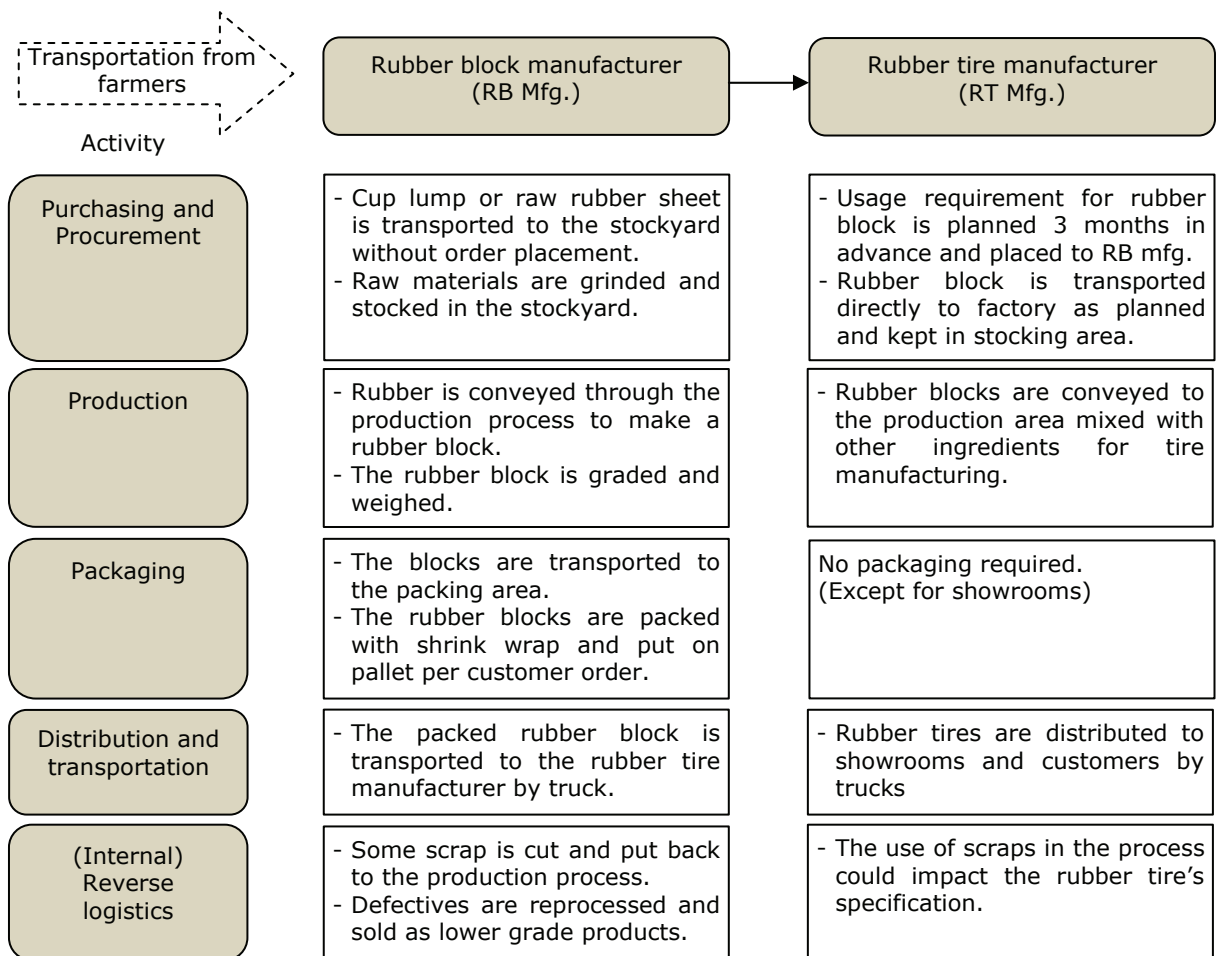
The concept of green supply chain management is a merging of two concepts: environmental management and supply chain management. Green supply chain management can, therefore, be seen as a concept of supply chain management initiating in order to improve effectiveness of supply chain to reduce environmental impact resulting from the operations of logistics activities throughout the product's lifecycle (Beamon, 1999). Lau (2011) and Beamon (1999) asserted that implementation of green supply chain focuses on collaboration among supply chain members to improve efficiency in managing and control flow of products and information taking into consideration of the impact on environment. Hervani et al. (2005) suggested that green supply chain and logistics should cover all logistics activities of the members in the supply chain including green purchasing or procurement, green manufacturing or production, green distribution and transportation, as well as reverse logistics. Managing of logistics activities in the supply chain can yield the greenness of the supply chain (Hervani, 2005; Lau, 2011; LMI, 2005). However, Kangang (2011) asserted that there are some issues in order to become success in green supply chain management. Firstly, the goal of greening supply chain should become aligned with business goals and must be communicated in the organization or among supply chain members. The organization should investigate and identify the transition to green supply chain which can help accomplish the business goal. For example, the use of environmentally friendly energy or increasing in efficiency of energy consumption can lead to reduction of energy cost. Secondly, the supply chain should be investigated for greenness as a single life cycle system i.e. from raw material extraction to final disposal of materials. The systematic view ensures that the entire supply chain is investigated and all possibilities to improve the greenness of supply chain become visible. Thirdly, the



analysis of green supply chain is vital. Green supply chain analysis would provide an opportunity to review all the process and activities for improvement. Lastly, the implementation of green supply chain should focus on reduction at source in order to reduce waste. It means that efficiency in resource utilisation should be increased to limit the production of waste instead of managing waste after it is generated.

## RUBBER TIRE SUPPLY CHAIN

This section presents the structure of rubber tire supply chain as well as all the activities in rubber block (mid-stream) and rubber tire (downstream) manufacturers. The rubber tire supply chain can be illustrated in figure 1. The structure of rubber tire supply chain is presented as headings on the top, and all the activities (with sub groups of activity) in each party are explained in detail.



**Figure 1** Rubber tire supply chain structure and activities

### The Structure of rubber tire supply chain in Thailand

The rubber tire supply chain consists of 4 main players; farmer, collector, rubber block manufacturer and rubber tire manufacturer. However, the scope of this study presented in figure 1 includes only rubber block manufacturer and rubber tire manufacturer. The supply chain activities in this study include the inbound transportation to the rubber block manufacturer, internal activities in rubber block manufacturer, internal activities in rubber tire manufacturer and the outbound transportation of rubber tire.

### **Supply chain activities of rubber tire products**

To obtain the information regarding the activities in each manufacturer, this study interviews all the departments who operates such activities, except the reverse logistics which is studied internally regarding the reuse of the scrap product or packaging materials.

#### Rubber block manufacturer

The activities in the rubber block manufacturer in this study begin with the receiving of rubber cup lump or raw rubber sheet. The rubber cup lump or rubber sheet is normally transported to the rubber block manufacturer's yard by the farmer or collector (only 20% of raw materials) on daily basis without purchasing order from the rubber block manufacturer. After that, the rubber raw materials are conveyed through the rubber grinding mill. Then the grinded rubber is stocked in the stockyard for no longer than one month. When the production required raw material as planned by the production planning department, the rubber material is conveyed through the production stations: pre-cleaning, cutter, breaker, shredder, creeper, extruder, oven, and lastly briquetting machine. Then the rubber block is graded and weighed. After the production line the rubber block are transported to the packing area where the rubber blocks are packed with shrink wrap and put on pallet per customer order. This manufacturer only stocks the rubber blocks which are ordered. Later, the packed rubber block is transported to the rubber tire manufacturer by a truck company.

#### Rubber tire manufacturer

Usage of rubber block and other raw materials are planned 3 months in advance in accordance with the production plan. After the ordered rubber blocks are arrived, they are counted transported to the stock area for about 3-7 days. When the production require, the rubber blocks are conveyed to the production area mixed with other ingredients for tire manufacturing. After manufactured, the tires are conveyed to warehouse with no packaging required. Later, the tires are distributed to showrooms and customers by owned trucks.

### **GREEN ASSESSMENT FOR RUBBER TIRE SUPPLY CHAIN**

The green assessment in this study is developed according to the green supply chain and logistics concept presented by Hervani et al. (2005). The green assessment matrix for rubber tire supply chain includes significant logistics activities: procurement, production related, packaging, transportation and distribution. Each activity is assessed in certain aspects which will be elaborated in the following parts.

#### **The matrix**

As mention earlier, the matrix of the green assessment implemented in this study covers all important activities in the rubber tire supply chain. This section presents the detail of the matrix.

#### Green procurement

The assessment of activity regarding the greenness of procurement activity including the procurement of raw materials or substances to replace hazardous materials, reduction in raw material usage, improvement of supplier's proficiency, reduction in resource usage, and raw material advancement.

#### Green production

Green production assessment in this study includes process design, product design, production efficiency improvement, and staff member satisfaction.

**Green packaging**

The green packaging activity is assessed through the selection of packaging material, thickness of packaging, and the reduction of packaging material usage.

**Green transportation and distribution**

The assessment of green transportation and distribution focuses on the use of fuel and maintenance of vehicles including the use of alternative or cleaner energy, management of truck loading, management of distribution trips, and truck maintenance.

**Reverse logistics**

In this study reverse logistics only involves reuse of scrap or other materials such as packaging materials in order that the use of natural resources materials can be reduced.

More detail of all activities in the rubber tire supply chain is presented in table 1.

**Table 1** Green supply chain assessment matrix

<b>Green Logistics and Supply Chain Management</b>
<p><b>Green Procurement</b></p> <ul style="list-style-type: none"> <li>• procurement to replace hazardous materials</li> <li>• reduction in raw material usage</li> <li>• improvement of supplier’s proficiency</li> <li>• reduction in resource usage</li> <li>• raw material quality improvement</li> </ul>
<p><b>Green Production</b></p> <ul style="list-style-type: none"> <li>• process design</li> <li>• product design</li> <li>• production efficiency improvement</li> <li>• staff member satisfaction</li> </ul>
<p><b>Green Packaging</b></p> <ul style="list-style-type: none"> <li>• selection of packaging material</li> <li>• thickness of packaging</li> <li>• reduction of packaging material usage</li> </ul>
<p><b>Green Transportation and Distribution</b></p> <ul style="list-style-type: none"> <li>• use of alternative or cleaner energy</li> <li>• management of truck loading</li> <li>• management of transportation trips</li> <li>• truck maintenance</li> </ul>
<p><b>Reverse Logistics</b></p> <ul style="list-style-type: none"> <li>• reprocess or modification of defectives</li> <li>• reuse of scrap</li> </ul>

**The assessment methodology**

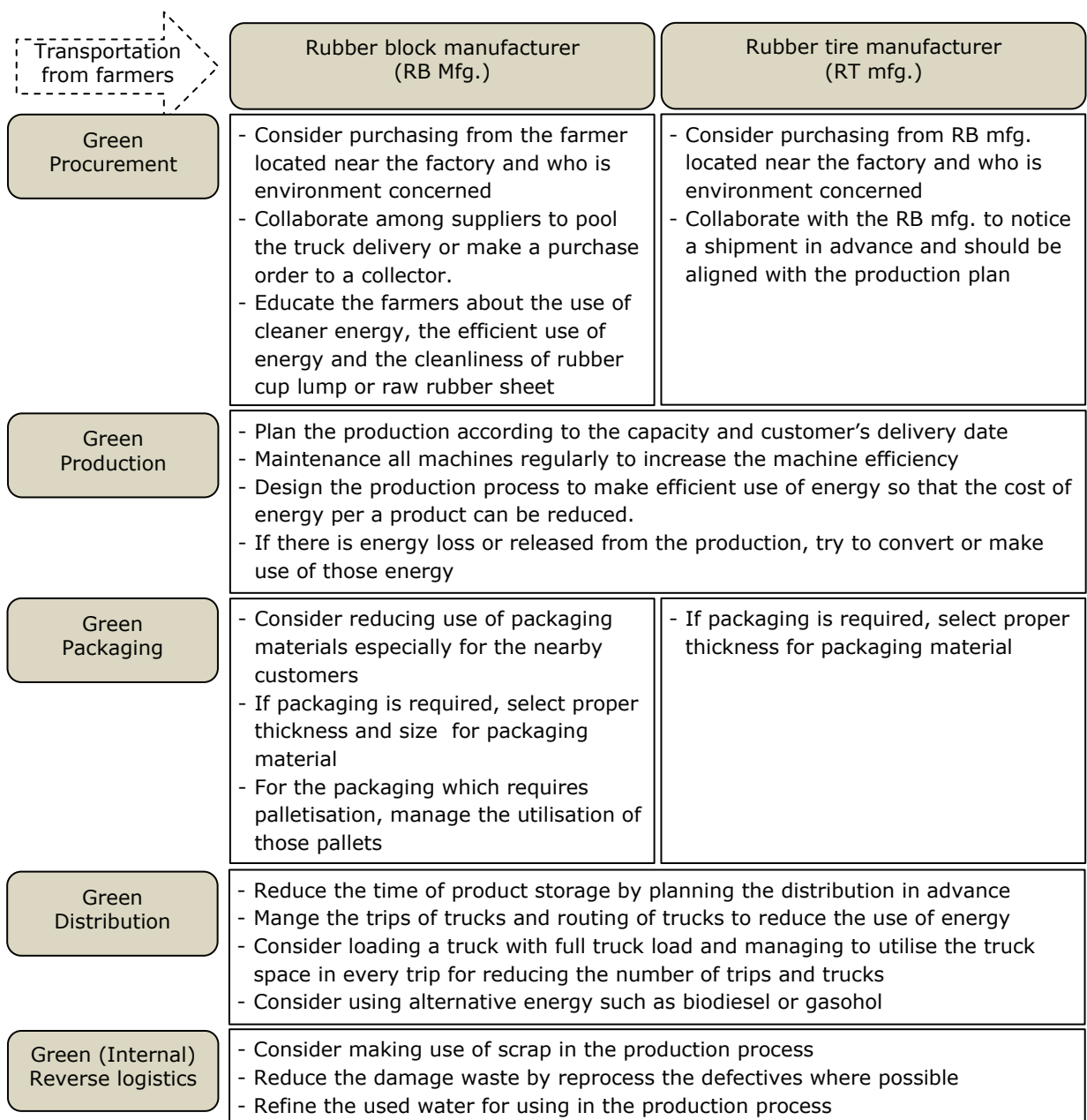
The framework of green assessment in table 1 is applied along with the focus groups and in-depth interview with panel of experts who are executives and practitioners in rubber industries. The experts suggested all the best practices of certain activities in rubber tire supply chain according to the framework. The best practices of rubber tire supply chain for rubber block manufacturer and rubber tire manufacturers are presented and will be discussed later.

After discovering the best practices in the rubber tire supply chain, the green assessment matrix is then applied to a rubber tire supply chain to evaluate against the best practice. The score 1 to 5 is given the practice of each activity where 1 means poor practice regarding greenness of certain activity and 5 means

best practice with green concerns. The scores are given by the experts and the executives of the organisation. Applying the green assessment matrix helps identify the hot spot of each company

### BEST PRACTICES FOR GREEN RUBBER TIRE SUPPLY CHAIN

Best practices for the green rubber tire supply chain have been extracted applying the matrix by the experts and professionals from the rubber tire supply chain industries via focus groups and in-depth interviews. The experts suggest that the rubber tire supply chain should take into consideration the greenness of the industry. The best practices are presented and classified into green supply chain activities as shown in figure 2.



**Figure 2** Best practices for green rubber tire supply chain

#### Rubber block manufacturer

In order that the rubber block manufacturer, the experts suggests that all supply chain activities should be green. The rubber blocks manufacturer should procure rubber cup lump or raw rubber sheet from the farm located near the factory and should plan the receiving of rubber. The suppliers should collaborate with each other to consolidate the delivery otherwise the RB Mfg. should consider buying from a collector who can consolidate the required rubber. Where possible, the suppliers should be educated about efficient use of cleaner energy. In the green production, the RB Mfg. should plan the production and regularly maintenance the machine. The production process should be efficiency in energy consumption. The packaging of rubber block should be used only when required and the selection of thickness and material of packaging should be selected properly. For the green distribution, the fleet management should be applied for the manufacturer with owned trucks. Otherwise, the trips and truck loading should be planned so that the number of trucks and trips required can be lessened. Lastly, the internal reverse logistics should implement recycle, reuse or reprocess of the defective rubber block or scrap so that wastes from the factory can be reduced.

### **Rubber tire manufacturer**

The rubber tire manufacturer should planned the production in advanced so that the requirement of rubber block and other material can be planned and notified to RB Mfg. Rubber block should be ordered from the nearby RB Mfg. For the green production the same practices as RB Mfg. can be applied to the RT Mfg. with more focus should be placed on the energy consumption and maintenance of machines. Fortunately, the packaging for rubber tire is typically not required. However, if the packaging is required the thickness and material of packaging should be selected properly. Similar to RB Mfg. the fleet management or truck loading and trips management should be applied. Internal reverse logistics in RT Mfg. should implement recycle, reuse or reprocess of the defective rubber block or scrap as well.

## **RESULT FROM THE ASSESSMENT OF THE CASE RUBBER TIRE SUPPLY CHAIN**

After obtaining the best practices of green rubber tire supply chain, the green assessment matrix is applied to assess a rubber tire supply chain as a case study against the best practices. The case supply chain consists of 2 manufacturers as per the frame presented earlier: rubber block and rubber tire manufacturers. The executives and experts are asked to score each supply chain practice. The score result of green assessment on the case rubber tire supply chain is displayed in table 2. The scores consist of greenness score of each activity in both rubber block and rubber tire manufacturer.

**Table 2** Results of green supply chain assessment in rubber block and rubber tire manufacturer (example from a rubber tire supply chain)

<b>Green Logistics and Supply Chain Management</b>	<b>RB Mfg.</b>	<b>RT Mfg.</b>
<b>Green Procurement</b>		
• procurement to replace hazardous materials	4	4
• reduction in raw material usage	4	4
• improvement of supplier's proficiency	3	4
• reduction in resource usage	4	4
• raw material quality improvement	4	4
<b>Green Production</b>		
• process design	4	3
• product design	4	4
• production efficiency improvement	4	3
• staff member satisfaction	4	3

<b>Green Logistics and Supply Chain Management</b>	<b>RB Mfg.</b>	<b>RT Mfg.</b>
<b>Green Packaging</b>		
• selection of packaging material	4	3
• thickness of packaging	4	4
• reduction of packaging material usage	4	4
<b>Green Transportation and Distribution</b>		
• use of alternative or cleaner energy	4	3
• management of truck loading	3	3
• management of transportation trips	4	3
• truck maintenance	3	3
<b>Reverse Logistics</b>		
• reprocess or modification of defectives	4	2
• reuse of scrap	4	2

The result from the case supply chain shows that both manufacturers in the rubber tire supply chain need improvement in many aspects. It can also indicate the hot spot which needs improvement. For the rubber block manufacturer, the focus of green improvement should be green procurement and green transportation and distribution. To improve green procurement practice of the rubber block manufacturer requires an improvement of supplier proficiency which is transportation from the farmer. Though manufacturer receive the cup lump or raw rubber sheet from the farmers located near the factory, each farmer or collector has their own transportation and transports cup lump or raw rubber sheet to the factory individually without cooperation or planning with other farmers or collectors. The green transportation practice in rubber block manufacturer should focus on the truck loading management with full or near-full truck load. This requires a delivery requirement planning of customers' delivery date. Also the truck used for delivery should be regularly maintained. For the rubber tire manufacturer, the improvement of green practices should aim at green production (including selection of packing materials), green transportation and internal reverse logistics. In the production process of the rubber tire case, there is inefficient flow of materials between stations which cause longer travelling distance. This inefficient flow of material also increases energy consumption to transport materials in the production area. Moreover, satisfactory of staff members would encourage the staff members to perform production efficiency improvement. The green transportation and distribution of this rubber tire manufacturer should be improved by increasing the use of cleaner energy, management of truck loading and delivery trips and maintenance of truck. The fleet management should be applied for green purpose and customer satisfaction. Moreover, the rubber tire manufacturer should research and develop the production process so that the scrap can be recycled and the defective products can be reprocessed.

## **DISCUSSIONS AND CONCLUSION**

For the green rubber tire supply chain, all activities in the supply chain affect the greenness of the supply chain. Thus, every single part of the entire supply chain must be green or taking environmental impact into account. Green rubber tire supply chain relies on green purchasing, green production, green packaging, green transportation and green reverse logistics. The major concerns regarding green purchasing is the use and inbound logistics of raw materials. For the green production, the process should be design to lessen the use of energy and the preventive maintenance should be applied. Green packaging should focus on reducing the use of materials where possible and the selection of proper types and thickness of materials. Greening the distribution practice concentrates on fuel consumption and the use of cleaner fuel. Lastly, the green reverse logistics consider reuse of scraps or other materials where possible. This project can be enhanced by cooperating the expert's opinion with carbon footprint. The combination between green supply chain assessment matrix and carbon footprint calculation could make the assessment more convincing.

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## **SECTION 3 – Risk and Disruption in Supply Chains**

### **SUPPLY CHAIN RESILIENCE: THE POSSIBLE APPLICATION OF TRIPLE BOTTOM LINE COSTING TO SUPPLY CHAIN RISK MANAGEMENT**

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Namibian German Centre for Logistics, UK

#### **Introduction**

Within the context of the supply chain industry, the long term value of an organization equates to the fiscal metrics used in the classical definition of enterprise modified by the sustainability (or capacity to endure) of the activity.

Logistics practitioners and academics design logistics solutions with varying degrees of resilience and robustness in response to both internal and external forces. Supply chain disruption events test the resultant operations. A 2010 survey recorded 45% of the respondents as experiencing supply chain disruption within the past year and of these more than 50% incurred a loss of over US\$1m (Banerjai et al, 2012). The industry is also experiencing more Black Swan incidents (Taleb, 2008) i.e. events that are a surprise to us and have a major impact on life, organizational value and sustainability.

The focus of this paper is on sustainability, how it should be gauged and how might supply chain resilience and triple bottom line costing (TBLC) influence the valuing of the organization. The underpinning research is based on previous work by the authors; it applies the principles proposed by Průša and Savage (2007) to the findings from a three round Delphic study (Gibson et al, 2011). The output of this has been examined in the light of other relevant literature to draw conclusions on the practical importance of supply chain resilience and the potential role of triple bottom line costing.

#### **Definitions**

Supply chain resilience: The ability of a system to return to its original state or move to a new, more desirable state after being disturbed (Christopher & Peck, 2004)

Supply chain risk appetite: The amount and type of risk that an organization is prepared to seek, accept or tolerate (Howard, 2009).

Supply chain risk tolerance: The maximum risk that can be taken before financial distress (Howard, 2009).

#### **Literature Review**

Waters (2011) ably encapsulates research into risk within supply chain operations as:

'If you collect any group of managers and ask them to discuss risk in the supply chain, they rarely agree about the meaning of either 'risk' or the 'supply chain'.

He goes on to describe eight physical features of a resilient supply chain as well as five relationship-based features, which include collaboration, confidence in partners, visibility and process management.

Altay and Ramirez (2010) hold that different disasters affect different levels of the supply chain and mitigation strategies need not be disaster specific, the best ones being composite disaster impact measures. Peck (2010) asserts that culturally determined perceptions of risk may vary greatly from one country to another and therefore impact risk perception differently throughout global supply chains. Reviewing the World



Economic Forum supply chain and transport risk survey, Wright and Datskorska (2012) and put forward five recommendations including the use of collaboration and visibility to enable effective international, management and governance processes across supply chains. Inadvertently, these visible and collaborative ways of working also propagate the conditions for the high adverse impact of Black Swan events (Marchese, 2012).

Ritchie and Brindley (2007) describe how risk and supply chain performance are interconnected and supply chain management (SCM) should evaluate the risk of changing structures and relationships prior to introducing any change into the chain.

Narusimham and Talluria (2009) present an operational focus and suggest organizations should become more flexible and agile to respond to supply chain risk through better internal integration as well as external integration and flexibility. Christopher (2010) defines the '4r's' supported by (SCM) in a modern world including reliability and responsiveness which both rely on supply chains being sufficiently agile to cope with unanticipated events.

The IBM (2010) survey recorded risk as the second highest issue in supply chain after visibility. But, whilst 69% of respondents formally monitored risk, only 31% manage performance and risk together. John et al (2012) surveyed over a 1,000 supply chain practitioners in July 2012 and found at least eight out of ten organizations had been hit by supply and demand side disruption over the previous two years.

Sodhi et al (2012) report three gaps pertinent to future research in this field, firstly there is no clear consensus in the definition of SCRM, secondly there is a lack of commensurate research on responding to supply chain risk incidents and finally there is a shortage of empirical research in the area of SCRM. From the perspective Value Chain Risk Management, Carter et al (2012) identify two risk dimensions, firstly the probability of an event occurring and secondly its impact upon value chain performance. Operationally this means the organization has the choices of: avoiding the risk, accepting the risk, shifting the risk to another party or mitigating the risk and Boer (2012) defines success through mitigation as being on time, in full and compliant. This supports the supposition that the value of an organization is the sum of its enterprise value and the sustainability (or compliance) of its activity.

Wilding (2011) describes a model for building resilience into the supply chain and this is illustrated in figure one. Simchi Levi (2010) reports that a \$10 increase in the price of a barrel of crude oil could produce a 7.9% increase per mile in EU transportation rates. This is reason enough for using a risk exposure index and measuring both the time taken to recover from supply chain disruption as well as the financial impact. Peck (2010) suggests a management system based on level one challenges at the local level through to level four challenges at the macro level, all of which may need a degree of redundancy or slack in order to assure resilience.

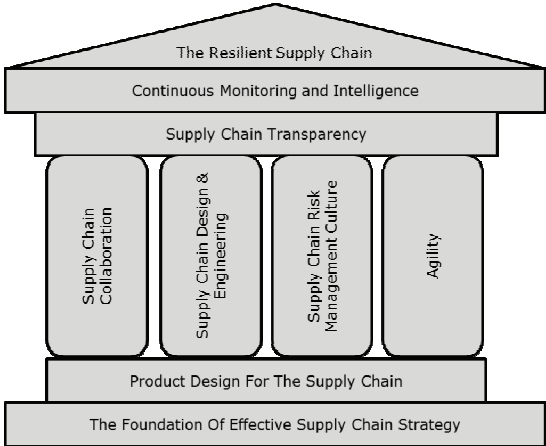


Figure 1 Resilient Supply Chain Model, Wilding (2011)

## **Description of Challenge**

The academic world of supply chain risk management and TBLC often debate an optimum state of organizational capability. In the commercial environment, organizations approach these topics based on their awareness, organizational maturity and their capacity for change. A number of permutations may develop across market sectors and within organizations that balance the demands of market based enterprise value with long term sustainability.

At the heart of this research is the simple question: how can organizations know if they have adopted the optimal balance of these factors to drive sustainability and long term growth? This does assume that there is a common understanding of the term sustainability, which is not the case. There are many perceptions, many of which are too narrow. A key feature of genuine sustainability is that it has both commercial and environmental components (Jenkins et al, 2012). Further, that in successful models, these will complement one another and not compete.

## **Research Work**

To assess the importance of risk in developing a supply chain strategy, a three round Delphi survey was conducted with a panel of constituents numbering 1,002 at the outset (Gibson et al, 2011). The final group of respondents had over 2,190 years of experience, two thirds occupied senior supply chain roles and represented a broad mix of own account and outsourced operators along with consultants to the industry. The results were compiled using a web based survey platform, which reduced the administrative burden in managing 12,000 pieces of data from 381 respondents. Pragmatically, consensus was based on majority answers to closed style multiple choice questions

The anonymous Delphi exercise took place during 2010 and 2011 and included questions on the following topics:

- Does your organisation have a supply chain strategy?
- Is there an up to date operations manual in situ?
- Do you measure the cost of your supply chain and how frequently?
- Do you conduct value chain analysis?
- Who will fund the collaboration required in the future supply chain?
- What does a good supply chain feel like?

The assessment of the possible influence of TBLC was based on a review of previous work and publications by the authors and others.

## **Results and Analysis**

**Risk & strategic management** - The panel were asked if they had a strategy or plan for the organization, over what period of time this extended and whether there was a current operations manual which could define the supply chain activity. To make the questions more relevant for the groups of respondents, the survey platform split the question sets for operators, logistics service providers and consultants. Key headings included;

### **1. Strategy and functional specification**

The majority of operators felt their strategic plans ran longer than the service providers perceived. Consultants generally felt customer's plans were built on even shorter timescales. Put simply, operators felt they plan over a longer period than their service providers perceive and the consultants felt they planned over an even shorter period.

A large proportion (but still a minority) of customers of logistics service do not have written functional specifications for any part of their supply chain. Further, operators are likely to have an operations manual but it may not be relevant and may be out of date.

## 2. Cost, value chain and defining success

Measuring costs is most likely to happen periodically or weekly, but a large proportion of respondents reported measuring costs only annually. Most respondents had not used value chain analysis to affect improvements in their supply chains, where used it was mainly in transport and stock holding. Benchmarking was not seen as a route to defining or confirming a successful supply chain, it appears that the industry was unwilling to share its learning's to improve standards and performance. This indicates that benchmarking is not used as part of continuous improvement initiatives.

When asked what a good supply chain "felt like", the following six areas were significant:

- Calmness / Quiet: When the contract is not making any 'noise' then everything is "OK"
- Contract renewal: If the contract is renewed then this must be evidence of success
- Industry sector: Apparently success criteria differs by industry sector
- Key Performance Indicators: Achieving these measures of internal performance deliver success.
- Satisfaction; If the customer is satisfied then that must mean success
- Customer Driven: The customer should drive success by setting targets they will be happy with.

he quality of 'calmness' appeared to be a common factor in operations that are deemed to be good as well as feel good. This probably suggests that both operators and service providers are 'composed' in their relationship which comes from feelings of trust and both parties accepting a mutual dependency. There were some significant other outlying comments on this topic and the answer-set remained divergent.

## Collaboration, risk and the future supply chain

Generally, collaboration is felt to be self-funding between all parties engaged in the activity. But, comments were varied and suggested whilst good partnerships would bring strength to the supply chain, self-funding is often a myth because there needs to be investment first in order to achieve the necessary improvements to reduce costs.

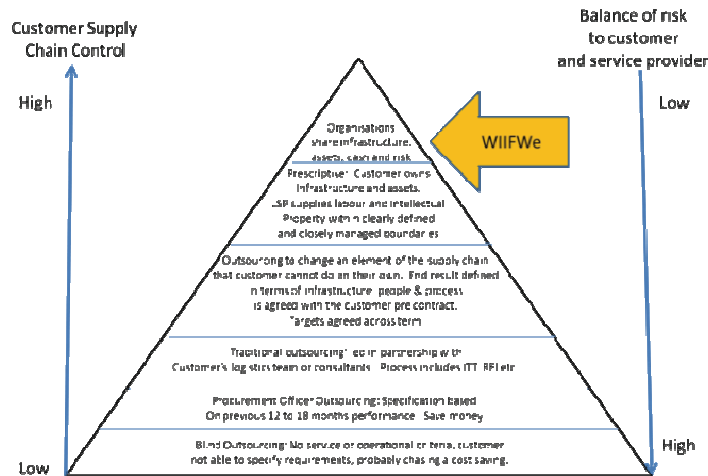


Figure 2 Outsourcing solutions vs control and risk

Customers of service providers felt they will fund collaboration through their own efficiencies or these efficiencies will be supported by all parties to the activity.

The academic world of logistics outsourcing defines several iterations and stratifications of logistics and supply chain outsourcing solutions. There are many service offerings and the nature of the industry allows for bespoke service offerings with an eagerness to avoid a one size fits all solution. Commentators are prescriptive in their responsibilities for customers of service providers to control and specify their businesses successfully and the ongoing role they have in managing the outsourced relationship. It is not clear what degree of risk each service offering entails for the customer and the service provider.

This risk based approach is illustrated in figure two which describes a pyramid of outsourcing solutions balancing them with the degree of control and risk inherent to the parties involved.

**Triple bottom line costing** - Griffiths and Savage (2007) discuss the downsides of globalization and conclude that whilst extended global supply chains offer great benefits in terms of extended markets, enhanced supplier bases, new products, etc. there are also losers, often from less developed countries. Importantly they also note that extended supply chains increase the adverse impact on the environment as well as risks to supply chain performance and escalating costs due to technical problems and over-reaching on the part of global sourcers.

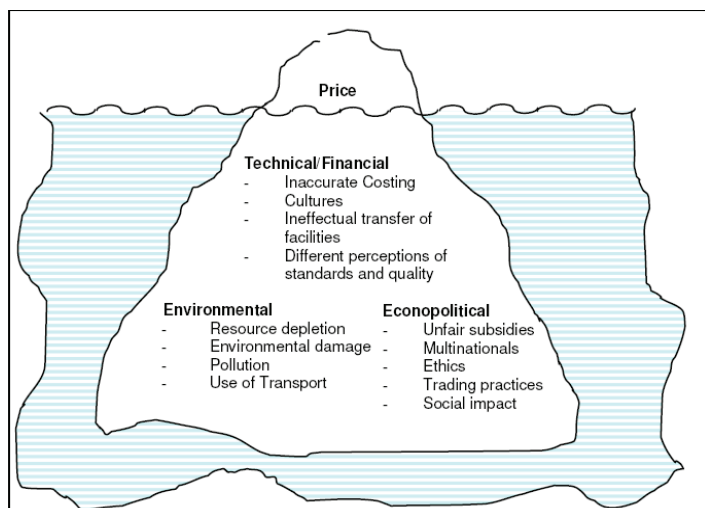


Figure 3 Price and hidden costs iceberg. Bailey et al (1998)

Menna et al (2007) propose a method of attempting to assess the impact on supply chains based on cost, risk, time and the environment, whilst Průša & Savage (2007) combine the two concepts and suggest that such costings should

recognize the “price and hidden costs” iceberg effect where many environmental, econopolitical and technical / financial costs that tend to be hidden – see figure three. They conclude that, before proposing further extension of supply chains, sources and marketers should use TBLC to take account of people, the planet as well as profit to ensure that sustainable in the future, rather than simply carrying out a conventional profit and loss calculation.

This may seem like an idealistic approach, but close examination of many of the principles used to improve the “greenness” of a supply chain also make good economic sense. For example, the use of vehicles with high fuel economy and practicing variable time based routing and scheduling will both lead to reduced fuels costs and environmental improvements (Maden et al, 2008). Further, the steps taken to reduce the environmental impact of supply chains (e.g. limiting the number of nodes in a chain or sourcing locally to reduce carbon emissions) will help to reduce risk and improve both their robustness and resilience, for example: their ability to recover from an unexpected, disruptive event.

**Discussion**

Against a background of an era of disruption and uncertainty (Christopher, 2010), formal risk management in the supply chain is at an immature state in its development. The pillars of the Wilding (2011) resilience house are collaboration, design, management culture and agility. The responses from the Delphi survey demonstrate there is little consistency in these areas and it may be viewed as a poorly informed area amongst supply chain operators, with many questioning the value of investing their time on the subject. In terms of strategy and functional specification the results suggest the constituent parties in the supply chain are not joined on strategic activity and have differing points of view dependent upon their position in the supply chain. This may compromise collaboration, agility and supply chain design. Supply chain risk management is often further hampered by not having current operations manuals which describe the current operation. The responses to the question of cost, value chain and defining success indicate the industry is not comfortable with benchmarking and has a varied view of what good looks like with no views expressed about resilience. This hampers collaboration and agility as the organization is not clear of its supply chain capability. The uncertainty is surprising because Competitive Benchmarking has been proposed as a vital component of service level definition and improvement for 20 years (Christopher, 1992). For the issue of collaboration, central to supply chain resilience (Lambert et al. 1996), respondents were reasonably positive and there was a willingness amongst operators to fund these initiatives.



So what practical application does this output have, what does a good approach look like that an organization can model its behaviors upon? Figure four summarizes the good and bad behavior traits drawn from results across the Delphi survey.

To have a positive approach to supply chain resilience,

**Figure 4 Good and bad behaviours for managing risk**

the organization must have a current strategy with a clearly defined set of objectives (which include risk management) balanced with competing priorities within the business. Supply chain familiarity will be evident with current operational manuals, highly visible costs and cost drivers working with clear service level management policies at the supply chain interfaces. Looking from the outside or 'the balcony view' the organization will be seen to be exhibiting a high degree of control on its supply chain and partners as well as a willingness and openness to engage in a collaborative style.

Supporting colleagues with relevant training in Supply Chain Risk Management is critical and this may be a challenge in this arena at the present time as the traditional industry bodies struggle to catch up with a concept referenced by Christopher and Peck as far back as 2004.

Combining and analysing the findings of the papers on the impact, costs and risks of global sourcing with that of Gibson's work on supply chain risk and resilience (2011) suggest that efforts to reduce environmental damage and avoid adversely affecting people's way of life can also help take much of the risk out of extended supply chains. Therefore, applying the principles of triple bottom line costing to operational and business decisions will not only enhance the life of the planet, but also reduce the risk components in individual supply chains. This in turn can enhance both the commercial and environmental sustainability of the companies concerned, thus improving their value.

### **Conclusion**

Building the resilient supply chain becomes an important strategic goal, clearly stated it aligns design and management culture through collaborative and agile working practices and the transparency of a well-controlled and monitored supply chain yields an enhanced organizational approach to risk. It is reasoned that supply chain costs will flatten as disruption costs reduce and organizational agility allows for different approaches and solutions to emerging issues.

By integrating risk into operations and business decisions we can be more responsive and agile to optimizing performance within the supply chain and mitigate the impact from events in the world around us. The value contribution is strengthened with greater sustainability in addition to the traditional measures of enterprise value so the value of the whole organization increases.

Bearing this in mind combined with the sustainability principles mentioned above, this paper proposes that making triple bottom line costing a part of the decision making process, particularly when considering extending or outsourcing a supply chain will enhance the value of the company, allow us to enjoy the benefits of living in a global village whilst enabling us to worry less about the legacy we leave for our descendants.

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## **BLACK SWAN RISK MANAGEMENT: THE MODERATION EFFECT OF RISK MITIGATION STRATEGIES**

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### **INTRODUCTION**

Many scholars have discussed supply chain risk mitigation on operational risks, but less on rare, highly influential, and retrospective predictable risks, such as natural disasters, epidemics, and socio-political crises. They are Black Swan risks (Taleb, 2007). More than disrupting supply chains, Black Swan risks even threaten companies' survival (Taleb, Goldstein and Spitznagel, 2009). Strategies, such as the Triple-A supply chain (Lee, 2004), robust strategies (Tang, 2006a), flexibility (Tang and Tomlin, 2008), agility (Braunscheidel and Suresh, 2009), and postponement (Yang and Yang, 2010), have been well discussed to provide insights to supply chain risk mitigation. However, little attention has been devoted to linking these risk mitigation strategies to focal company performance to evaluate their efforts. Although it is intuitive that risk mitigation strategies moderate the relationship between supply chain risks and focal company performance, the vast majority of the extant literature is descriptive and anecdotal. The purpose of this study is to test the moderating role of risk mitigation strategies in the relationship between Black Swan risks and focal company performance. As operational risks and Black Swan risks are not mutually exclusive, we postulate that companies can utilize existing strategies with more targeting solutions to minimize their exposure to Black Swan risks.

### **LITERATURE REVIEW**

Nowadays, market competition takes place no longer between individual companies but between supply chains (Li, Ragu-Nathan, Ragu-Nathan and Subba Rao, 2006; Trkman and McCormack, 2009). The quality, cost and risks of a product or service offered in the market is related to not only the focal company's capabilities, but also the supplier network that provides inputs to the enterprise (Modi and Mabert, 2007). This explains why there has been a substantial rise in supply chain risk management (SCRM) research in the past few years (Rao and Goldsby, 2009). Manuj and Mentzer (2008) pose that SCRM is the identification and evaluation of risks and consequent losses and implementation of appropriate strategies. We follow the same approach to review literatures: identify risk sources, develop risk mitigation strategies, and evaluate them through focal company performance. Therefore, we first make a summary of risk sources, with an emphasis on Black Swan risks.

#### **Risk Sources**

Black Swan was first capitalized by Taleb (2007) in his book *The Black Swan: The Impact of the Highly Improbable*. He summarized three attributes of a Black Swan: "First, it is an outlier, as it lies outside the realm of regular expectations, because nothing in the past can convincingly point to its possibility. Second, it carries an extreme impact. Third, in spite of its outlier status, human nature makes us concoct explanations for its occurrence



after the fact, making it explainable and predictable” (Taleb, 2007, xvii). When linking recent Black Swan events with literatures, we identify three main sources: regulatory, legal, and bureaucratic risks, infrastructure risks, and catastrophic risks (Wagner and Bode, 2008).

Regulatory, legal and bureaucratic risks refer to the legal enforceability and execution of supply chain relevant laws and policies (e.g., trade and transportation laws) as well as the degree and frequency of changes in these laws and policies (Wagner and Bode, 2008). The former issue always reflects on administrative barriers (e.g., customs, regulations, and corruptions) for the setup or operations of supply chains. For instance, a weak rule of law is problematic for all who do business in China, particularly burdensome for newer, smaller private businesses. In this case, *Guanxi* (personal connections that executives developed in societies) serves as a substitute for formal institutional support (Xin and Pearce, 1996). Despite having a contract, McDonald’s was forced to relocate in Beijing to accommodate real estate development by Hong Kong billionaire Li Ka Shing, because of his strong *Guanxi* with high-ranking officials in China (Pearce and Robinson, 2000). This barrier requires more investment in local expertise, connection maintenance, and organizational learning. Meanwhile, legal changes are often sudden and difficult to anticipate. For example, environment legislation in European countries now requires product traceability and the establishment of reverse logistics systems. In order to meet such environmental requisites, firms frequently get involved in more complex supply chains and incur higher supply chain costs (Wagner and Bode, 2008).

The risk source “infrastructure” includes disruptions that materialize from the infrastructure that a firm maintains for its supply chain operations (Wagner and Bode, 2008). For example, in 2004, IBM announced that yield problems at its plant in East Fishkill, New York, contributed to the \$150 million first-quarter loss by its microelectronics division (Tang and Tomlin, 2008). Another famous example is from Philips in New Mexico (U.S.), where a fire at the local plant site caused a production breakdown worldwide at various manufacturing sites. Ericsson lost \$400 million in sales, because it employed the Philips as a single source. Ericsson’s production was disrupted for months, when the Philips plant shut down after the fire (Chopra and Sodhi, 2004). Infrastructure risks include socio-technical accidents such as local human-centred issues (e.g., vandalism, labour strikes, and industrial accidents), IT failures or breakdowns, and yield uncertainty (e.g., machine deterioration and loss of investment) (Chopra and Sodhi, 2004; Blos, Quaddus, Wee and Watanabe, 2009).

Catastrophic risks come from pervasive events that having a severe impact on the area of their occurrence (Wagner and Bode, 2008). Such events can be socio-political instability, epidemics and natural hazards (Oke and Gopalakrishnan, 2009; Blos et al., 2009). Since 2001, the destructive impact of terrorism on firms’ supply chains has received much attention (Sheffi 2001). Terrorist attacks affect supply chains either directly (e.g., destruction of logistics infrastructure) or indirectly (e.g., port closures for security reasons) (Czinkota, Knight, Liesch and Steen, 2005). Moreover, flu pandemic (ECDC, 2010) and cholera outbreak (MSPP, 2011) in recent years have significant worldwide influences. Tsunamis, earthquakes, hurricanes, and floods are also a constant threat to many regions of the world and to their firms in particular (Rao and Goldsby,

2009). Both epidemics and natural disasters have negative consequences on supply chains, mainly through working force, production facilities and transportation systems. Due to the globalization of markets and a surge in globe-spanning supply chain operations, local catastrophes have increasingly indirect global repercussions (Wagner and Bode, 2008).

### **Risk Mitigation Strategies**

After applying Black Swan risks to supply chain management, we are able to develop risk mitigation strategies accordingly. After a careful literature review, we categorize extant risk mitigation strategies into two types -- buffering and bridging (Bode, Wagner, Petersen and Ellram, 2011). Buffering strategies attempt to gain stability by establishing safeguards that protect a firm from disturbances that a trading relationship confers. Bridging strategies attempt to manage uncertainty through engaging in "boundary-spanning" and "boundary-shifting" actions with a trading partner. For instance, increasing capacity, acquiring redundant suppliers, and aggregating demand belong to buffering strategy, while external integration is a good example of bridging strategy. Although they constitute independent approaches, buffering and bridging are not mutually exclusive. For example, a firm may achieve volume flexibility (buffering) through better information exchange with a key trading partner (bridging).

Buffering is an effort to reduce a firm's exposure to the current trading partner and to mitigate the detrimental consequences of disturbances that the relationship may confer (Carroll, 1993; Chattopadhyay, Glick and Huber, 2001). To this end, the focal firm can build up slack resources to act as "shock absorbers", such as larger inventories, flexible production processes, redundant suppliers, and product designs that are not dependent on a specific supplier (Tang, 2006b). All these "shock absorbers" can be classified as one of the two aspects: internal buffering or external buffering. Internal buffering is based on the idea of modularity, while external buffering is related to the control of the supply chain network.

According to Baldwin and Clark (1997), modularity is an approach for organizing efficiently the design and production of complex products and processes. Complex tasks are decomposed into simpler elements so that they can be managed independently and yet operate together as a whole. Modularity increases exponentially the number of possible configurations achievable from a given set of inputs, greatly increasing the flexibility of a system (Schilling, 2000). A motivation behind modularity is to gain flexibility and cost savings through economies of scale (Mikkola, 2003). For example, modular design enables the utilization of postponement strategy, a strategy that enables a firm first to produce a generic product based on the total aggregate demand of all products, and then to customize the generic product later on. In the context of disruption recovery, postponement strategy offers a cost-effective and time-efficient contingency plan that allows a supply chain to reconfigure the product quickly in the event of supply chain disruption (Tang, 2006a). Modularity can also deal with supply uncertainty within similar products. Considered the whole life cycle of similar products, components that undergo the same life cycle processes should be grouped into one module for improving, e.g. disassemblability, maintainability, upgradability, reusability, and recyclability, thus merging the supply base of certain components (Umeda, Fukushima, Tonoike and

Kondoh, 2008). Based on this similar design, a retailer can use pricing mechanism to entice customers to choose similar products that are widely available. For example, when Dell encountered supply disruptions from their Taiwanese suppliers after an earthquake in 1999, Dell could immediately deploy a contingency plan by offering special "low-cost upgrade" options to customers if they chose similar computers with components from other suppliers (Martha and Subbakrishna, 2002).

With the help of modularity, strong control of the supply chain network can further benefit the focal firm by building external buffering. Such control can lie in using quantity flexible contracts, alternative suppliers and suppliers' alternative plants, etc. Let us continue the case of Philips accident. Nokia is another major customer of the Philips plant. After knowing the accident, Nokia almost immediately began switching its chip orders to other Philips plants, as well as to other Japanese and American suppliers. Because of its modular design and strong control of the supply chain network, Nokia suffered little during the crisis and even stole market shares from Ericsson (Sheffi, 2005). Moreover, external buffering often overlaps with bridging strategy. Li & Fung, the largest trading company in Hong Kong for durable goods, established a supply network of over 4,000 suppliers throughout Asia to provide a great flexibility to shift production among suppliers in different countries quickly when a disruption occurs in a particular country. Consider the case when the Indonesia Rupiah devalued by more than 50% in 1997. Many Indonesian suppliers were unable to deliver their orders to their U.S. customers, because they were unable to pay for imported materials. In this case, Li & Fung adapted quickly by shifting some production to other suppliers in Asia (external buffering) and by providing financial assistance to those Indonesian suppliers affected to ensure business continuity (bridging). With an adaptive supply chain network, Li & Fung was able to serve their customers in a cost-effective and time-efficient manner in a short run as well as a long run (Tang and Tomlin, 2008).

Bridging is internal to a current relationship, as it is an effort to manage resource dependencies by enlarging a firm's influence over them (Pfeffer and Salancik, 1978). Less than six hours after the Kobe earthquake on January 17, 1995, when relief trucks were crawling at two miles per hour on the highways, Seven-Eleven Japan, a \$21 billion convenience store chain, aligned with its suppliers to use 7 helicopters and 125 motorcycles to deliver 64,000 rice balls to the city (Lee, 2004). Their quick-response won the hearts of many Japanese at that time.

Although the benefit of bridging strategy is obvious, most trading partners faced with taking an action that benefits their firm versus one that benefits the chain will choose the former (Narayanan and Raman, 2004). Thus, Lee (2004) argues that incentives should be organized in such a way that all parties' interests are aligned. The focal company should redefine partnership terms to share risks, costs and rewards for improving supply chain performance and relocate incentives so that players maximize overall chain performance while also maximizing their returns from the partnership. For instance, *Guanxi*, an administrative barrier for the setup and operations of supply chains in China, also has its positive side. In fact, *Guanxi*-based personal relationships are the quintessential basis for all business transactions in China. People do business only with those they know and trust. Negotiations are undertaken more obliquely than in the West, often focusing on long-term goals rather than specific current objectives. Business relationships are designed to enhance *Guanxi* and thereby lead to other opportunities (Pearce and Robinson, 2000). Luo and Chen (1996) found that, in business dealing underscored by *Guanxi*, both buyers and sellers benefit. The seller benefits by providing

favourable credit terms with extended payment periods resulting in concordant sales growth. The buyer benefits from more favourable cash flow circumstances and increase operational flexibility. The well-developed *Guanxi* network provides increased assurance that one's exchange partner will not act opportunistically. With no clear forecast of when, and if, rules and regulations in the Chinese insurance industry will emerge, maintaining *Guanxi* networks provides Chubb Insurance, an American insurance provider, with a sense of security through reliable relationships with current commercial clients (Standifird and Marshall, 2000). The development of *Guanxi* reflects the idea of bridging strategy. *Guanxi* will not be a threat, but an opportunity to help deal with other Black Swan risks in China, if the focal company can utilize the idea of bridging strategy to pursue a long-term orientation.

### **Performance Measures**

Risk mitigation strategies are only acceptable if company performance can be improved by imposing these strategies. With respect to service, firms generally develop measures to assess such specific elements as order cycle time, order fill rates, damage rates, error rates in picking orders, etc. (Brewer and Speh, 2000). For instance, Wagner and Bode (2008) used logistics performance and customer satisfaction to evaluate supply chain performance. Another well-known aspect is related to financial performance. The short-term objective of logistics management is to reduce inventory and cycle time, while long-term objective is to increase market share and profits (Tan, Kannan and Handfield, 1998). Thus, financial metrics have served as a tool for comparing organizations and evaluating their logistics performance over time (Holmberg, 2000). For example, Hendricks and Singhal (2003, 2005) used the observable share price and shareholder value of the announcing firm as the measures of firm performance.

These measures are critical parts of any logistics management system, but they are not always focused on measuring, motivating, and optimizing intra-firm and inter-firm performance (Brewer and Speh, 2000). When we enlarge the idea from logistics management to supply chain management, evaluation methods that only rely on service and financial measures are not well suited. A balanced performance evaluation of supply chain management should help organizations not only in monitoring their operations, but also in improving their internal and external functions of business, such as engineering and design applications, production, quality improvement, materials management, quick response, gaining lost market shares, proper implementation of business strategies, etc. (Bhagwat and Sharma, 2007). Therefore, the balanced scorecard (BSC) will be discussed below.

The BSC framework was created by Kaplan and Norton (1992). It provides a comprehensive performance measurement system, balancing the inclination to overemphasize financial performance by incorporating metrics related to long-term profitability, namely, customer satisfaction measures, business process measures, and innovation and learning measures (Brewer and Speh, 2000). Users can specify different goals in each perspective, and identify an appropriate measure for each goal.

The customer perspective aims at capturing customer opinion about the company and its products. When linking this perspective to supply chain performance, we include not only service measures, but also manufacturing measures related to certain products. For example, the yield problem of IBM plant reduced its effective capacity and limited its ability to meet customer demand, leading to quality problems, shortages and price surging in processors (Tang and Tomlin, 2008). Thus, we specifically address a

combination of customer values, namely, product and service quality, flexibility, and price (Brewer and Speh, 2000; Li et al., 2006).

The internal perspective asks what must be done internally to meet and exceed customers' needs. Even when confronting with Black Swan risks, companies should still maintain an on-time delivery of qualified products with reasonable cost. Seven-Eleven Japan serves as a good example that they arranged rush deliveries of 64,000 rice balls shortly after Kobe earthquake with a little extra cost (Lee, 2004). Therefore, the predominantly non-financial measures used here tend to focus on three performance attributes: (1) quality control measure; (2) time control measure; and (3) cost control measure (Brewer and Speh, 2000; Li et al., 2006).

The financial perspective shows whether the company's strategy, implementation, and execution are contributing to bottom-line improvement. This is the most common perspective to evaluate focal company performance. Nearly every case study in SCRM will mention the financial performance of the focal company. For instance, the capability to influence customer choice enabled Dell to improve its earnings in 1999 by 41% even during a supply crunch (Martha and Subbakrishna, 2002); Li and Fung's supplier network helped to earn its reputation in Asia and enjoy continuous growth in sales from 5 billion to 17 billion Hong Kong dollars from 1993 to 1999 (Tang, 2006a); Nokia boost its market share from 27% to 30% within six months of Philips fire accident, while Ericsson's dropped from 12% to 9% (Sheffi, 2005). Thus, financial goals can be simplified as: to survive, to succeed, and to prosper. Survival can be measured by cash flow and return on investment; success by market share, profit margin on sales and sales growth; and prosperity by growth of market share and growth in return on investment (Kaplan and Norton, 1992; Li et al., 2006).

The innovation and learning perspective provides a continuing basis to delight and retain customers. After a Black Swan event happens, it will show the focal company's speed to deal with such event. For example, after learning about Philips supply disruption, Nokia responded immediately by reconfiguring the design of their basic phones so that the modified phones could accept slightly different chips from Philips other plants and other suppliers (Tang, 2006a). Hence, the focus of this perspective rests on learning capabilities, such as process improvement and product development (Brewer and Speh, 2000; Li et al., 2006).

### **Moderation Effect and Research Framework**

In practice, the effectiveness of risk mitigation strategies can be tested by comparing future performance with performance before utilizing certain strategies. However, in academic research, we confirm this effectiveness through moderation effects. A moderator is a qualitative or quantitative variable that affects the direction and/or strength of the relation between an independent variable and a dependent variable (Baron and Kenny, 1986). In this study, the independent variables are three Black Swan risks, and the dependent variable is focal company performance. We have shown the negative impact of Black Swan risks on company performance via some cases. Thus, we first expect the same relationship will be reflected through our empirical data. Moreover, examples have demonstrated that certain risk mitigation strategies functioned well to offset Black Swan risks, sometimes even turning risks to opportunities. Hence, in our empirical study, risk mitigation strategies should serve as moderators that alleviate or even change the effect of Black Swan risks. To summarize, we form the following hypotheses and our research framework (Figure 1):

H1: The higher the regulatory, legal and bureaucratic risks, the lower the focal company performance.

H2: The higher the infrastructure risks, the lower the focal company performance.

H3: The higher the catastrophic risks, the lower the focal company performance.

H4a: Buffering strategies moderate the relation between the regulatory, legal and bureaucratic risks and the focal company performance.

H4b: Buffering strategies moderate the relation between the infrastructure risks and the focal company performance.

H4c: Buffering strategies moderate the relation between the catastrophic risks and the focal company performance.

H5a: Bridging strategies moderate the relation between the regulatory, legal and bureaucratic risks and the focal company performance.

H5b: Bridging strategies moderate the relation between the infrastructure risks and the focal company performance.

H5c: Bridging strategies moderate the relation between the catastrophic risks and the focal company performance.

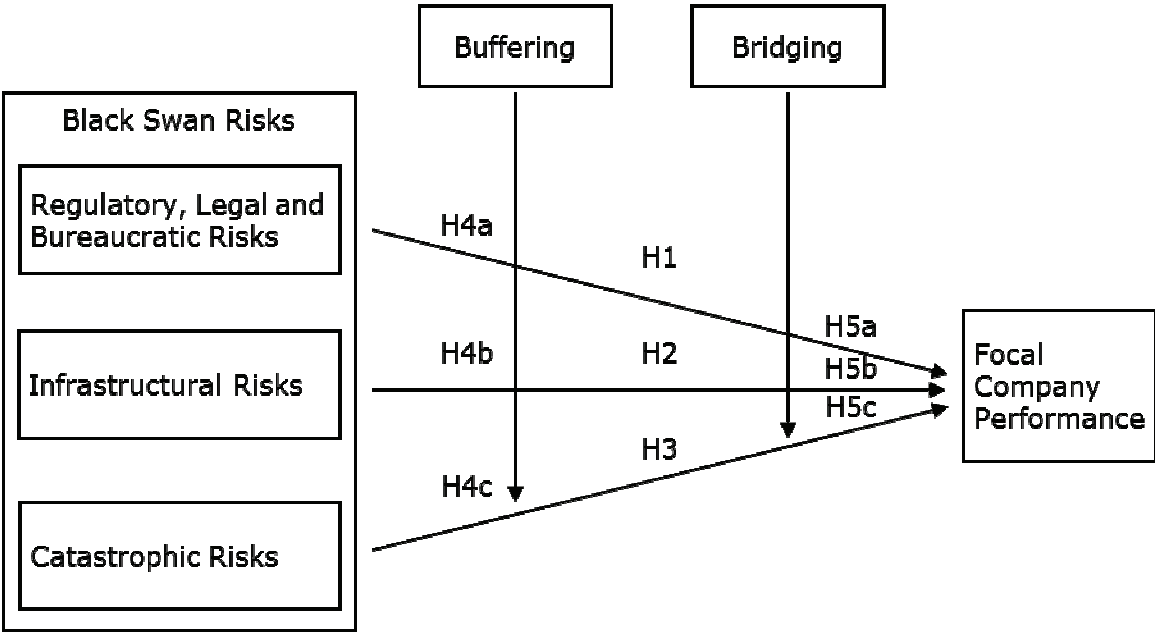


Figure 1: Research framework

## **METHODOLOGY AND EXPECTED FINDINGS**

A questionnaire has been generated after an extensive literature review. Most of the items are adopted from existing questionnaires. Our target groups are senior managers in purchasing, logistics, operations, or supply chain management departments. Now we are at pre-test phase.

The moderation effect of risk mitigation strategies is expected to be found. Detailed strategies with more targeting solutions will be provided to minimize company's exposure to Black Swan risks.

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## **PORTFOLIO MODELS OF B2B RELATIONSHIPS – BARRIERS TO SUPPLIER RISK MANAGEMENT**

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### **INTRODUCTION**

Today, companies must deal with an important challenge which is increasing uncertainty of the business environment [Simangunsong, Hendry and Stevenson, 2012]. There are many reasons why this environment is volatile and extremely demanding, for example: high competition in global conditions, increasing customer requirements, emergence of new threats (terrorism [Sheffi 2001], natural disasters), financial crisis [Blome and Schoenherr, 2011], shortening product life cycle. Finally, implementing the new strategies and business practices reducing number of suppliers and cycle times, eliminating buffers of time, inventory and additional production capacities in supply chain [Zsidisin, Ragatz and Melnyk, 2005]. The problem concerns especially the international supply chains because they are more complex and extended. Moreover, they operate in changing, differential conditions (legal, political, cultural etc.) which make them strongly exposed to a wide variety of external and internal disruptions [Jüttner, Peck and Christopher, 2003; Peck 2006]. Manuj and Mentzer [2008a] point following types of supply chain risk: supply, demand, operational, security, macro, policy, competitive and resource. We observe in recent years that the risk results in many disruptions [Kleindorfer and Saad, 2005; Tang 2006, Manuj and Mentzer, 2008b]. They can cause the great losses. Time based competition needs activities decreasing vulnerability of flow processes and programs building the supply chains resilience. In response to the needs of business practice the Supply Chain Risk Management (SCRM) concept was described and supported by risk management models [Jüttner, Peck and Christopher, 2003; Chopra and Sodhi 2004, Tang 2006, Kern et al 2012]. One of the way of dealing with the supply chain risk and continuity problems is the responsible cooperation with suppliers in the field of risk management [Hallikas et al 2004]. It is one of the key areas of the SCRM concept, sometimes described as a Supplier Risk Management, an important application in supply chain IT solutions.

The purpose of this paper is to present the supplier risk management issue in terms of the portfolio models described in the literature, and show the results of the conducted research on the polish market. One of the aims of the survey was to identify what kind of barriers to effective supplier risk management companies recognize.

### **RISK IN PORTFOLIO MODELS – LITERATURE REVIEW**

The element of risk has its unique place in portfolio models of B2B relationships. No doubt, the first and the most popular model is Kraljic model [Kraljic 1983]. It describes the risk as a difficulty in managing supply situation (number of suppliers, technological changes, entry barriers etc.). The higher risk refers to the strategic suppliers and partners providing bottleneck items.

Risk is a combination of the probability of an event and its consequences [ISO/IEC Guide 73:2002]. The most common types of risk are: strategic and operational one. Strategic risk is connected with achieving high level objectives of the company [COSO 2004, p. 3] strategic decisions influencing the structure of the supply chain (number of suppliers, localization, product etc.). Operational risk means "the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events, and includes legal risk" [Directive 2006/48/EC]. They both occur in relationship with suppliers. The strategic risk means in the worst case, losing the partner. For the strategic suppliers this is rather random situation, but if the cooperation falls apart, the consequences are huge. According to the bottleneck suppliers, the probability of this

problem is higher because those suppliers are not fully engaged in the cooperation and can withdraw from it easily. In turn, the consequences are similar, although the items do not have high importance. This is because the supply situation is difficult and may indicate for the purchaser lack of additional supplier on the market and long-term disruption. On the other hand, the operational risk to cooperation with strategic suppliers is rather small, because those partners are usually well-developed and improving their processes systematically while bottleneck suppliers use their advantage and do not always comply with the agreement fully. It results in disruptions during communication process.

In the next portfolio model, authors [Krapfel, Salmond and Spekman, 1991] identify the segments of suppliers basing on the two variables: "interest commonality" and "relationship value". The high strategic risk can be identified especially for the situation when two of those variables are high or only the value of relationship is high. It concerns the cooperation with "partners" or "rivals". Whereas the high operational risk characterizes the relation of the high interest but low relationship value. It means that relationship with "friends" requires urgent improvement to reduce the risk of disruptions, for example through supplier development programs.

Ellram i Olsen [1997] use in their model the same variables as Kraljic but they point additionally the other model variables: "strength of the relationship" and "supplier attractiveness". The strategic risk is connected with dependencies, that is why it is high when the strength of relationship is significant. The size of risk is mainly determined by size of the consequences hear. On the other hand, for the situation with a supplier of high attractiveness (financial, technological and organizational performance) – low operational risk can be identified. It means that a partner is reliable and adds an important value to the product on the favorable conditions.

Monczka and Trent [1998] also examine the variable "supply risk" in their model. The second variable is a "profit contribution". Taking into account the second variable, strategic risk can be high for the suppliers determining competitive advantage of the final product in a significant degree. While the operational risk appears for the cooperation with suppliers providing the purchaser with materials which are necessary or even critical for the production although they influence a value of the product in a small way.

In Bensaou [1999] model the strategic risk is connected with dependences in a supplier-purchaser relationship. Dependencies mean investments in the cooperation of both sides. The bigger investment the bigger dependency. When each partner engages a lot of time and money in developing the resources supporting the relationship, it is a strategic partnership with the high strategic risk. The size of the risk results from the potential consequences which would appear when the relationship breaks down. The risky situation for a company is also when the enterprise invests more than a supplier. In this situation a "captive buyer" suffers from the operational risk too. The advantage of supplier means a great uncertainty and the potential disturbances for which consequences supplier does not have to feel responsible.

In the next portfolio model [Kaufman, Wood and Theyel, 2000], an advanced "technology" and "collaboration" mean significant strategic risk. On the other hand, the operational risk is noticeable when the relationship involves an advanced technology but simultaneously the cooperation is not developed enough and the communication with so called "technology specialist" fails regularly.

The interesting variables in portfolio model pointed Nellore and Söderquist [2000]. They take into account which side provides the specification and an engagement of the partners (OEM and suppliers) in the product development. High strategic risk (consequences of losing the supplier) arises during the cooperation with partners who are mature, provides the purchaser with an advanced specification and cooperates smoothly on the product development. In this model the nature of an operational risk cannot be pointed clearly. Still child suppliers who get the specification from the client can be a source of this type of risk during product designing or daily orders execution.

Svensson [2004] described model basing on "suppliers commitment" and "commodities importance" variables. The strategic risk is high when two of them are high (cooperation with family suppliers) or for the situation when the first is low and the second is high (cooperation with business partners). Similarly for the latter variant the high operational risk can be identified.

Pagell, Wu and Wasserman [2010] underline in their portfolio model a new approach to the procurement which take into account the sustainable development issue. The authors pay attention not only to the variable "supply risk" following Kraljic but also on an aspect of the risk to TBL (Triple Bottom Line) understood as the risk to profits, environment or/and society. This risk has an operational character. At least one of those tree types of the risk is high for the cooperation with suppliers providing strategic items and for the providers of the leveraged items two types of risk are low and the third one is high.

## **METHODOLOGY**

One of the objectives of the research was to identify the barriers which companies observe during managing risk in relations with suppliers. The study was conducted among the companies functioning in Poland on the B2B market and with ISO 9001 certificate. The survey was carried out between October 2011 and January 2012. A source of the companies' data was HBI base. The 3224 questionnaires in paper form were sent. The 165 fulfilled and sent back questionnaires were approved for further analysis. The companies had a possibility to mark free number of the answers. The results are set together in a Table 1.

## **FINDINGS**

There are many reasons why managing risk in relationships with suppliers is difficult. The most frequent barrier is lack of involvement of suppliers in the improvement of cooperation' (78,18%). Without the commitment of both sides of the cooperation the improvement of flow processes in relationships supplier-purchaser is rather impossible. Moreover, commitment means also the willingness to bear the costs of improvements. Unfortunately most companies (76,36%) identify a reluctance of suppliers to manage risk in view of the need to incur additional costs. Similarly, sharing information, knowledge, problems with partners is crucial for reducing risk. Another barrier is that suppliers do not see any need to implement new solutions (technical and organizational) (69,09%).The study shows that suppliers do not want to share information about ongoing processes (75,15%). It can result from a low level of awareness of business partners on the issue of risk management (70,30%) or lack of knowledge of suppliers about the extreme risks which may disturb ongoing flow processes (70,30%). The lack of awareness or knowledge is connected with a lack of qualified and experienced employees (70,30%) and a 'lack of adequate training on the market in the practical use of the knowledge on risk management in the supply chain' (63,03%). This can lead to 'difficulties in the preparation of safety procedures' (60,61%).

All barriers defined in the survey were pointed by over a half of the companies who took part in the research. Comparing the particular segments it can be noticed that in most cases the big companies, entities with foreign capital, offering products on the foreign market and of international spatial range identify barriers more often than companies small/medium enterprises with polish capital and national supply chain.

## **SUMMARY**

Supplier risk management is a complex issue and requires much attention, especially today when the supply chains compete with time and flexibility. It should be an important tool used during Supplier Relationship Management. Although portfolio models are not a sufficient source of the information about the supplier risk, they provide a basic approach for risk analysis and development of risk management strategies adjusted to suppliers segments. Ensuring the continuity of flow processes in supplier-purchaser relationship requires a commitment of both sides. The recognition of the barriers for managing risk in relationship with suppliers is crucial to overcome them successfully. The

results of the study shows that the companies operating in international supply chains are highly aware of those barriers. These enterprises operate in heterogeneous, volatile conditions what requires wide knowledge about the effective ways of how to build reliable and agile processes. These companies are exposed to a great uncertainty coming from the cooperation with foreign business partners often located at a great distance what impedes a communication with suppliers and a supervision of providers. The next research should concentrate on ways to overcome the barriers for supplier risk management.

**Table 1. Barriers, which company identifies for risk management in relationship with suppliers. The results from the study conducted in 2011/2012 in Poland. The comparison of segments for the following criteria: number of employees, capital, products offered on specific market and the spatial range of the company in percentages are presented.**

Barriers, which company identifies for risk management in relationship with suppliers	Total	Number of employees			Capital		Products offered on specific market		Spatial range	
		under 50	51-500	over 500	national	foreign	domestic	domestic and foreign	national	international
<b>N</b> the size of the segment	<b>165</b>	<b>58</b>	<b>92</b>	<b>15</b>	<b>131</b>	<b>34</b>	<b>20</b>	<b>145</b>	<b>53</b>	<b>112</b>
lack of involvement of suppliers in the improvement of cooperation	78,18	75,86	82,46	80,00	61,07	82,35	70,00	79,31	71,70	82,14
reluctance of suppliers to manage risk in view of the need to incur additional costs	76,36	65,52	71,21	80,00	61,07	88,24	55,00	79,31	62,26	83,93
reluctance of suppliers to share information on ongoing processes	75,15	70,69	76,84	66,67	50,89	79,41	60,00	77,24	64,15	81,25
low level of awareness of business partners on the issue of risk management	70,30	67,24	73,09	73,33	55,98	67,65	70,00	70,34	62,26	75,00
lack of knowledge of suppliers about the extreme risks which may disturb ongoing flow processes	70,30	62,07	67,47	66,67	50,89	70,59	65,00	71,03	60,38	75,89
lack of qualified and experienced employees (suppliers', company's and on the labor market)	70,30	60,34	65,59	73,33	55,98	64,71	70,00	70,34	62,26	75,00
reluctance of suppliers to implement new solutions (technical and organizational)	69,09	56,90	61,84	73,33	55,98	73,53	55,00	71,03	52,83	77,68
lack of adequate training on the market in the practical use of the knowledge on risk management in the supply chain	63,03	51,72	56,22	66,67	50,89	61,76	50,00	64,83	50,94	69,64
difficulties in the preparation of safety procedures	60,61	55,17	59,97	73,33	55,98	64,71	50,00	62,07	45,28	68,75

Source: own study (2011/2012).

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# **SUPPLY CHAIN RISK MANAGEMENT IN THE BRAZILIAN AUTOMOTIVE INDUSTRY: A CASE STUDY**

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## **INTRODUCTION**

The development of the concept of Supply Chain Management (SCM) has created global supply chains, increased the outsourcing of products and processes, and reduced the supplier base and inventory volumes, among other aspects. At the same time, companies have witnessed the growth of events that have negatively affected their SCM, such as terrorist acts, natural disasters, economic crises and company bankruptcy. Therefore, the risk exposure of supply chains has increased significantly. Accordingly, the concept of Supply Chain Risk Management (SCRM) has emerged and been defined as risk management through a coordinated approach among the supply chain members in order to reduce the vulnerability of the chain as a whole (Christopher & Lee, 2004).

On the other hand, during the XX century, the automotive industry developed and became a reference for practically all other industrial sectors. Furthermore, during the first decade of the XXI century, it has been challenged to meet a series of new, growing requirements dictated by the market, such as to produce vehicles more economically and sustainably, minimize polluting emissions, seek alternative fuels, as well as meet the needs of the so-called emerging markets. Alongside this, with the current stagnation in the industrialized countries, the automotive industry has been rapidly restructuring, as much in terms of producer markets as those of consumers. Thus, countries like China, Brazil and India have emerged as major vehicle producers and consumers (Pires *et al*, 2012). In this sense, a recent research divulgated by KPMG International (Global Automotive Executive Survey 2012) forecasts that, in 2016, China will be leading the world automotive market, and Brazil, currently the fifth world producer, should reach third position. However, despite the importance and representativeness of the automotive industry, risk management studies in the sector, such as that conducted by Thun and Hoenig (2009), are still rare. In this context, this paper has the purpose of presenting some preliminary results of an ongoing research on SCRM being conducted in the Brazilian automotive industry, which seeks to identify and analyze its key elements, such as the main causes of its risks and their respective mitigation procedures.

## **SUPPLY CHAIN RISK MANAGEMENT**

Defining risk is among the most sensitive points in the SCRM literature. Several authors have conducted elaborate studies of the subject, among whose definitions some intersections can be detected. Two of the main aspects of risk, frequently present in numerous works, appear to be the likelihood of it taking place (commonly referred to as "probability") and its potential to produce or spread any sort of loss, or various outcomes (Christopher and Peck, 2004). Manuj and Mentzer (2008), after interviewing managers from different manufacturing sectors, reached two basic definitions for risk: potential losses and their probability of occurrence. Corroborating these findings, there is an equation that shows the most common type of definition in risk management: "Risk = Probability (of a given event) x Severity (negative business impact)" (Christopher and

Peck, 2004; Harland et al., 2003). In the same sense, Ritchie and Brindley (2007) list three common points among risk definitions in the SCRM literature: (1) likelihood of occurrence, (2) consequences, and (3) causal path. In turn, the Royal Society (1992, *apud* Khan and Burnes, 2007) outlines that risk is a combination of two key factors: (1) probability of occurrence; and (2) magnitude of its consequences. These aforementioned consequent losses resulting from risky events are often expressed in financial terms, given the essential role capital plays in organizations. Thus, risks can be associated to costs and pursuit of their reduction, as well as the supply chain money flow itself (Spekman and Davis, 2004). Harland et al. (2003) point out the existence of six types of loss: financial, performance, physical, psychological, social, time. Complementarily, there are two factors affecting the nature of risks, which are speed and frequency (Manuj and Mentzer, 2008). According to the authors, "speed of risk can be divided into the rate at which the event leading to loss happens, the rate at which losses happen, and how quickly the risk event is discovered (...). Frequency is a measure of how often a similar kind of risk event happens". Therefore, the general definition adopted in this paper is that risk is both the probability of any unexpected condition to happen and the whole range of losses engendered by the diverse impacts of such occurrence.

Furthermore, the topic of risk management usually makes use of some specific terms, such as the following: Resilience is a term borrowed from Materials Engineering, which has been widely used in the SCRM literature. It describes the ability of a system to recover its initial state after a stressful situation, without any change in its nature (Christopher and Peck, 2004; Kleindorfer and Saad, 2005; Ponomarov and Holcomb, 2009; Klibi and Martel, 2012). Agility plays an important role in SCRM as it is the key element for risk management strategies, paving the way towards efficient contingency plans and risk mitigation (Braunscheidel and Suresh, 2009; Kleindorfer and Saad, 2005; Faisal et al., 2006; Wieland and Wallenburg, 2012; Norrman and Jansson, 2004). Flexibility, as well as agility, is referred to by some authors as inter-connected to resilience and competitive advantages. It is defined as the ability to adopt different variables in businesses, without incurring losses (Skipper and Hanna, 2009; Kleindorfer and Saad, 2005; Braunscheidel and Suresh, 2009; Chopra and Sodhi, 2004; Tang and Tomlin, 2008; Harland et al., 2003; Manuj and Mentzer, 2008; Schmitt and Sing, 2012; Tang, 2006; Tomlin, 2006).

There is a wide variety of definitions in risk classification, particularly due to different perspectives. Various authors propose a definition centered on the company: internal and external risks (Olson and Wu, 2011; Christopher and Peck, 2004; Manuj and Mentzer, 2008). Identifying correlations between both supply and demand with risks is also important in such categorization (Manuj and Mentzer, 2008), as they are involved in supply chain-related risks, providing us with a broader point of view than risks focused on the company alone. In brief, in order to facilitate the comprehension of risk typologies, some steps must be followed. Tang and Tomlin (2008) provide us with an embracing classification of risks, contributing enormously to the model adopted in this section. Herein, risks shall be divided into three distinct ambits: (1) risks exclusive to the company; (2) whole supply chain risks (which also include both supply and demand risks); and (3) risks generated by outside forces (risks external to the supply chain).

For the first aspect, focal company risks, it is necessary consider processes and control as key points to establish a standard for quantifying risk within the corporation (Christopher and Peck, 2004; Tang and Tomlin, 2008). Secondly, supply chain risks deal with the inability of the focal firm to meet customer demand because of unfavorable events (Zsidisin, 2003; Manuj and Mentzer, 2008; Norrman and Jansson, 2004), and

lack of visibility along the supply chain (Christopher and Lee, 2004). Here, supply risks and demand risks lie within supply chain scope. Supply risks are related to the suppliers and the risks inherent to effectively matching the supply to the demand process. Therefore, meeting supply and demand in quantity, quality and variety is a challenging aspect of globalization, for companies worldwide (Tang and Tomlin, 2008). Finally, supported by Jüttner et al. (2003), there is a category of risks external to the supply chain. Essentially, these can be related to politics, economics and natural phenomena.

Moreover, in another categorization, some authors also classify risks into ten different categories, which are: demand, delay, disruption, inventory, manufacturing, capacity, supply, system, sovereignty and transportation (Tummala and Schoenherr, 2011). However, it is important to note that it is possible to encompass all these ten categories in the three ambits previously described. In turn, managing risk within companies and in their respective supply chains demands systematic action. Process nomenclatures and designations in general differ from author to author, but, as Norrman and Jansson (2004) state, "the steps are similar". Basically, risk management is aimed at understanding sources of risk and minimizing their eventual impacts. It involves preparation to react in difficult situations as well as to be proactive, preventing losses and elaborating contingency plans to tackle any negative condition. Based on the publications of authors such as Hallikas et al., (2004), Norrman and Jansson (2004), and Kern et al. (2012) it is possible to outline a four-step path for risk management, such as illustrated in Figure 1 and discussed below.

*Figure 1: Main steps of a risk management process*

Risk Identification basically consists of identifying imminent risks to the focal company and its supply chain. Thus, risk identification aims at embracing all possible hazards that might affect the supply chain. Managers must take into account upcoming uncertainties in order to recognize each of them and be able to manage such circumstances proactively (Hallikas et al., 2004), prioritizing the most significant risks (Kern et al., 2012). Thus, risk managers must label risks as substantial or not, and then move on to the next stage, risk assessment.

Risk Assessment basically covers evaluation of the likelihood of occurrence of risks and estimation of their impact. Kleindorfer and Saad (2005) cite three subdivisions in the process of assessing risks: (1) probabilistic risk assessment using tree analysis; (2) vulnerability assessment using team-based approaches towards specific agents; and (3) decision analysis.

Risk Mitigation seeks to address potential risks and take the right countermeasures. This process usually includes at least four stages, generally structured as follows: (1) risk avoidance, (2) risk transfer, (3) risk sharing, and (4) risk reduction (Hallikas et al., 2004; Kern et al., 2012; Norrman and Jansson, 2004). *Avoiding risks* consists of eliminating processes, stages and any other situation that might trigger any risky event. *Transferring risks* to another company in the supply chain is of high value if the company receiving the risk has greater capability to deal with it. Besides this example of such a situation (resorting to insurance companies), some alternatives can also be considered as risk transfer, such as moving inventory liability, changing delivery times of suppliers and outsourcing. Both by contractual means and improved collaboration, risks could

alternatively be *shared* among supply chain partners. *Reducing risks* refers to decreasing both their probabilities and consequences. Good examples of risk impact reduction are multiple sourcing and diversification, having management teams within the company, extra inventory (buffering) and improving risky operational processes. Zsidisin (2003) state that supply risks can be minimized by improvements in processes between the purchasing firm and its supplier, as described by the authors: forming strategic alliances and developing suppliers, so that communication is improved and thereby drawing the goals of all the organizations closer, reducing risks in the operations among them. The authors also underline the adoption of buffering strategies in order to tackle supply risks. Tang (2006) adds the importance of supplier selection, which should follow some criteria, such as the supplier's technological capability and financial stability.

Risk Monitoring, in turn, basically consists of monitoring and effectively controlling all SCRM stages/processes.

Finally, regarding SCRM in the auto industry, studies published in the literature are still very incipient. One of the few published works is by Thun and Hoenig (2009), who performed a survey in 67 companies in the automotive sector, especially auto parts suppliers in Germany. In this research, the authors identified the main motivating factors of risk, in descending order of importance: (1) globalization, (2) variations in products, (3) outsourcing and reduced supplier base, (4) focus on efficiency, (5) centralized distribution and (6) centralized production.

## **RESEARCH DESIGN**

Coping with today's increasing frequency and magnitude of change in technology and management approach, case study has become one of the most powerful forms of research in operations management (Voss et al., 2002). It allows investigation of a contemporary phenomenon within its real life context, especially when the boundaries between them are not clearly defined. Therefore, it is recommended for current issues and situations in which the researcher simply observes the facts and seeks to understand, systematize and analyze them (Yin, 2003; Voss et al, 2002). Thus, case study is particularly useful when there is uncertainty in defining constructs (Voss et al., 2002), and it has been recognized as being useful to examine basic questions, as in the present study.

In this sense, the entire research project was designed to be conducted in two distinct steps. The first, reported in this article, is exploratory, in which an in-depth case study is performed, taking as the focal company a large European automaker operating in Brazil. This was conducted (in the period between late 2012 and early 2013) through interviews, based on a simple semi-structured questionnaire, of the country's executive in charge of the automaker's SCRM issues (embracing its inbound, internal and outbound supply chain processes). As suggested by Yin (2009), these empirical data were then supplemented with factory visits to view the operations, as well as analysis of the documentation available. Furthermore, in order to guide and systematize the case study, a simple framework was constructed, divided into three main stages as illustrated in Figure 2, and described below.

Figure 2: Framework for the case study

Firstly, the risks were identified, classified and labeled. Secondly the main causes (drivers and/or triggers) of these risks were determined. Finally, the key procedures used to mitigate them were established.

Concerning the second research step, from the experience of the case study (step one) and an extensive literature review, a survey was designed, which is now in the implementation phase. It will cover over 50 companies, these being restricted to around ten automakers and their first-tier suppliers and customers (immediate supply chain), which were selected through an intentional sampling process. It will be concluded and published in another, more comprehensive article in the near future.

## **RESULTS/ANALYSIS**

Considering especially the characteristics of each stage of the supply chain, the framework (Figure 2) was applied considering the three steps of the automaker's supply chain in the country. Accordingly, data collection was focused on the steps of the inbound, internal and outbound supply chain. In each of these three steps, a major risk was identified. Additionally, for each of these three steps, two risk causes were identified, as well as their corresponding procedures for mitigation. The main results of the case study are summarized in Table 1 and discussed below.

In the inbound supply chain, the main risk identified was *supply disruption*, i.e., the possibility of the company suffering a supply break in its production units in the country. The first cause identified for this was the company's difficulty in developing and managing business relationships with some first-, second- and even third-tier (usually local) suppliers, sometimes not completely satisfied with the relationship basis, especially concerning the prices paid by the automaker. Usually this is a complicated, delicate point in many customer-supplier relationships, but it has grown significantly in the automotive industry in the country due to the increasing level of competitiveness in the local market and a consequent increase in pressure for cost reduction. As the main procedure for risk mitigation, the company has tried to use its experience and bargaining power to revisit the foundations (basis) of the relationship, as well as use formal procedures for monitoring supplier performance, thus avoiding being surprised by a lack of supplies. The second cause identified for supply disruption is the significant growth in volume of imported items in vehicles produced by the company in Brazil. This has led to greater dependence on logistics infrastructure abroad and in this country, which not has developed at the same pace as its economy. In this respect, the current saturation of some aspects regarding the country's logistics infrastructure (especially in relation to its ports), as well as the bureaucracy and delays in customs processes, often represent major obstacles to establishing a more reliable supply process. Concerning the procedures for mitigating this risk, the company has revised its policies and procedures for inventory management and imported items. Therefore, the company has strived to develop alternative local suppliers, with a consequent increase in the volume of local purchases. However, the level of safety inventories of imported items has also increased.

Table 1: Main case study results

Supply Chain	Risk	Risk Causes	Risk Mitigation
Inbound	Supply disruption	(1) Difficulty in developing and managing business relationships with some first-, second- and even third-tier (usually local) suppliers, sometimes not completely satisfied with the prices being paid by the automaker.	(1) Use the company's experience and bargaining power to revisit the foundations (basis) of the relationship, as well as use the formal procedures for monitoring supplier performance.
		(2) Growth in volume of imported items for vehicles, leading to greater dependence on the logistical infrastructure of the country, which has not been developed at the same pace as the economy.	(2) Review of policies and procedures for inventory management and imported items, with a consequent increase in the volume of local purchases and safety inventory of imported items.
Internal	Assembly line stoppage	(1) Stoppage for corrective maintenance, due to overload triggered by continuous operation close to full capacity.	(1) Investments in new productive resources, more rigor in preventive maintenance, and sharing capacity among production units worldwide
		(2) Stoppage for corrective maintenance due to a lack of predictive maintenance.	(2) Review of policy and procedures for investment and replacement of productive resources
Outbound	Failures in the distribution system	(1) To meet the growing demand for vehicles in the country, having to compete with other automakers and to share a very limited capacity supplied by a small number of qualified logistics service providers operating in the sector.	(1) Development and establishment of new logistics service providers, which usually have a relatively long set-up period.
		(2) Highways and cities overloaded with vehicles across the country, leading to increased legal restrictions on the time allowed for access to large urban centers, as well as reduction of the truck drivers' working day.	(2) Review of policy and procedures for the distribution of new vehicles and spare parts, usually with increased costs.

In the internal supply chain, the main risk identified was *assembly line stoppage*. The first cause identified for this is corrective maintenance, which is usually triggered by overload caused by continuous operation close to full capacity. Regarding the procedures for mitigating this risk, the company has made investments in new productive resources, as well as introduced more rigor in its preventive maintenance procedures. The challenge here is to combine the improvement in equipment performance without harming the current accelerated pace and volume of production. Moreover, when possible, another alternative procedure used by the company has been to partly reallocate the workload

among their factories in the country or even among plants located in different countries. Such an alternative procedure is practically exclusive to a company with global operations, but imposes a relatively greater time and complexity on its implementation. The second cause identified is the stoppage of assembly for corrective maintenance due to lack of predictive maintenance. Here it is important to remember that predictive maintenance can be considered a variation of preventive maintenance, where components are replaced or checked before presenting any defect. This is usually done based on studies that determine the so-called "Maximum Time Between Failures", which is not so easy to perform when a factory is undergoing a period of work overload. Regarding the procedures for mitigating this risk, the company has sought to revise its predictive maintenance policy and procedures, as well as its investment in and replacement of productive resources.

In the outbound supply chain, the main risk identified was *failure in the distribution system*, embracing both new vehicles and spare parts. The first cause identified for this is the current challenge of meeting the growing demand for vehicles, having to compete with other automakers installed in the country, as well as sharing a very limited capacity on the part of a small number of qualified logistics service providers operating in the sector. This creates a situation where the delivery of new vehicles to dealers usually follows a schedule dictated by the logistics providers, which does not necessarily represent what is scheduled (or desired) by the automaker. With respect to the procedures to mitigate this risk, the company has made efforts to develop and establish new logistics service providers. However, this process usually has a relatively long set-up period. The second cause identified is the current overload of vehicles on highways and cities across the country, leading to increased legal (governmental) restrictions on the time allowed for access to large urban centers, as well as a reduction in the truck drivers' working day. From the company's perspective, it is clear this has negatively affected (especially in terms of cost and delivery) its distribution processes, covering both the distribution of new vehicles and spare parts. Concerning the procedures for mitigating this risk, the company has sought to review its policy and procedures for the distribution of new vehicles and spare parts, but, generally, it is now having to incur increased costs.

## **CONCLUSIONS**

The study deals with a highly representative company in the automotive industry worldwide and a long, positive history of operation in the country. Thus, although restricted to one company, it is quite representative from the exploratory aspect. Moreover, as a pioneer (on the subject) case study in the country, it presents a series of new insights that will be useful in the formulation and design of future, broader research. Also, the simple framework built and implemented in the three supply chain steps (inbound, internal and outbound) of the automaker proved to be useful and fulfilled its purpose. Concerning the company under study, in general terms, it is possible to state that in belonging to a globalized corporation, it has tried to conduct its SCRM with an integrated approach, taking into account its local particularities and the corporate guidelines on the subject. This will clearly ensure that it will provide a higher level of flexibility and resilience than if it acted as a productive unit alone. Meanwhile, if research on SCRM in the world still has several unfilled gaps (as usually propagated in the literature), in Brazil it is certainly just beginning, even in the automotive industry.

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# CONSIDERATION OF THE STOCK CHARACTERISTICS OF A SYSTEM THAT FEATURES BOTH IMMEDIATE SALES AND NON-IMMEDIATE SHIPPING

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## ABSTRACT

To cope with the sluggish performance in their real, physical stores, an increasing number of supermarkets are embarking on sales via the Internet. Supermarkets that offer online sales need to handle both sales for real store customers and sales for online customers. There are two alternative schemes for shipping goods for online customers: the *shipping-from-store* scheme, in which existing stores ship the goods, and the *shipping-from-center* scheme, in which distribution centers ship the goods. We have considered a supermarket that sells goods both in real stores and online, and compared different strategies for shipping goods to online customers. Specifically, we first compared the volumes of stock of two shipping schemes. Scheme A makes good use of the existing facilities by shipping goods to online customers from stores. In Scheme B, the center ships goods to online customers. We have then compared Scheme B with Scheme C, which uses a separate center to ship goods to online customers. It has been found qualitatively that Scheme B, which holds stock in a smaller number of locations for a shorter length of time, requires a smaller stock than Scheme A. It has also been shown qualitatively that Scheme B, in which the stock at the center is used to meet both the demand from the stores and the demand from online customers, requires a smaller stock than Scheme C. From the perspective of the required volume of stock, Scheme B, the scheme of using an existing center to ship goods to both stores and online customers, is the most advantageous.

## INTRODUCTION

### Background

To cope with the sluggish performance in their real, physical stores (**Table 1**), an increasing number of supermarkets are embarking on sales via the Internet [1]. This mode of sales is called "online sales" and a supermarket which offers this is called an "online supermarket." Online supermarkets in Japan typically sell more than 1,000 products, some even handling about 30,000 products[2]. Fresh food is delivered the same day that it is ordered, meaning that the shortest time it takes for delivery is only 2 to 3 hours. Products are shipped 3 to 5 times a day.

Supermarkets that offer online sales need to handle both sales for real store customers and sales for online customers. In real stores, goods are sold on the spot. In online sales, one or more orders received from each customer via the Internet, are generally put together and the goods ordered are shipped to the customer at intervals during the day. In this way, these retailers handle a mix of demands for immediate sale and for non-immediate shipping, a mix unknown in the past.

Table 1 Change in sales of major business types (trillion yen)

Business type	Year 2001	Year 2011	Increase or decrease
Department stores	8.6	6.2	↘
Supermarkets	15.9	12.7	↘
Convenience stores	6.7	8.7	↗
Drug stores	2.7	5.6	↗
Online shopping	2.5	4.7	↗
Home centers	3.8	2.7	↘
Total of all types of retailer	136.8	134.0	↘

Source: Ministry of Economy, Trade and Industry

There are two alternative schemes for shipping goods for online customers: the *shipping-from-store* scheme (used by e.g., SEIYU, Ito-Yokado), in which existing stores ship the goods, and the *shipping-from-center* scheme (used by e.g., Hankyu Kitchen yell, SUMMIT Netsuper), in which distribution centers ship the goods[1]. The shipping-from-center scheme can be further classified into a scheme using existing distribution centers and a scheme using separate distribution centers dedicated to online sales.

### **Objective**

For supermarkets that offer online sales, it is essential to examine their profitability by studying how these alternative schemes for product shipping affect their stock characteristics; i.e., how their stock levels change over time. This paper compares the stock characteristics of these product shipping schemes that features both immediate sales and non-immediate shipping.

### **How our study relates to past studies**

Reference 3 considered a specific example of an online supermarket that adopts the shipping-from-center scheme, described the characteristics of this scheme, and indicated that the use of existing distribution centers can be effective. Reference 4 focused on the case of a supermarket that adopted the shipping-from-store scheme, and used a spatial competition model to examine how its competition with other supermarkets could evolve and how this competition could affect its profitability. Reference 5 illustrated the developments in the strategies and business models of online supermarket retailing, based on the empirical evidence gathered in the UK. Reference 6 discussed and empirically tested a conceptual framework for electronic physical distribution service quality (e-PDSQ) from the consumer's perspective.

However, no studies have been found that look at both the demand in the real physical stores and that from online customers, and discuss how different product shipping strategies can affect the supermarket's stock management characteristics.

## **THREE SCHEMES FOR SHIPPING GOODS FOR ONLINE CUSTOMERS, AND THE APPROACH TAKEN IN THIS STUDY**

### **Three schemes for shipping goods for online customers**

Three schemes can be conceived for shipping goods to online customers, as shown in **Fig. 1**. In Scheme A, the store holds the stock for both store customers and online customers and ships goods purchased by online customers. In Scheme B, the distribution center holds the stock both for online customers and for restocking stores, and ships goods to online customers. In Scheme C, a distribution center for online customers is set up separate from the center for restocking stores. As an online supermarket grows in size, its strategies for shipping goods may evolve. It may be generally expected to adopt Scheme A or B initially because these schemes make good use of existing facilities and thus are easy to implement. As the supermarket grows, it may shift to Scheme C, in which a new, separate center is set up for shipping goods to online customers.

### **Study approach**

We will first compare Schemes A and B, both of which use existing facilities, in terms of the stock characteristics. We will then compare Schemes B and C, in both of which distribution centers ship goods to online customers. Schemes A and B differ from each other in the way goods are stocked in addition to the way stocking spaces are used and the average distance of delivery to online customers. In Scheme A, goods for online customers are stocked in the distribution center and stores (with some stock being held in delivery vehicles). In Scheme B, these goods are stocked only in the distribution center. This difference is expected to affect the total volume of stock in each scheme. So, we first compare Schemes A and B in terms of the total volume of stock.

In Scheme B, the demand from stores and that from online customers share the same distribution center, along with its stock and its resources for handling goods. The flip side is that the center needs to handle a mix of shipping to stores and shipping to online

customers. In Scheme C, on the other hand, the two types of demand use separate resources, but each center needs only to handle a single type of shipping, either shipping to stores or shipping to online customers. We will compare Schemes B and C, again in

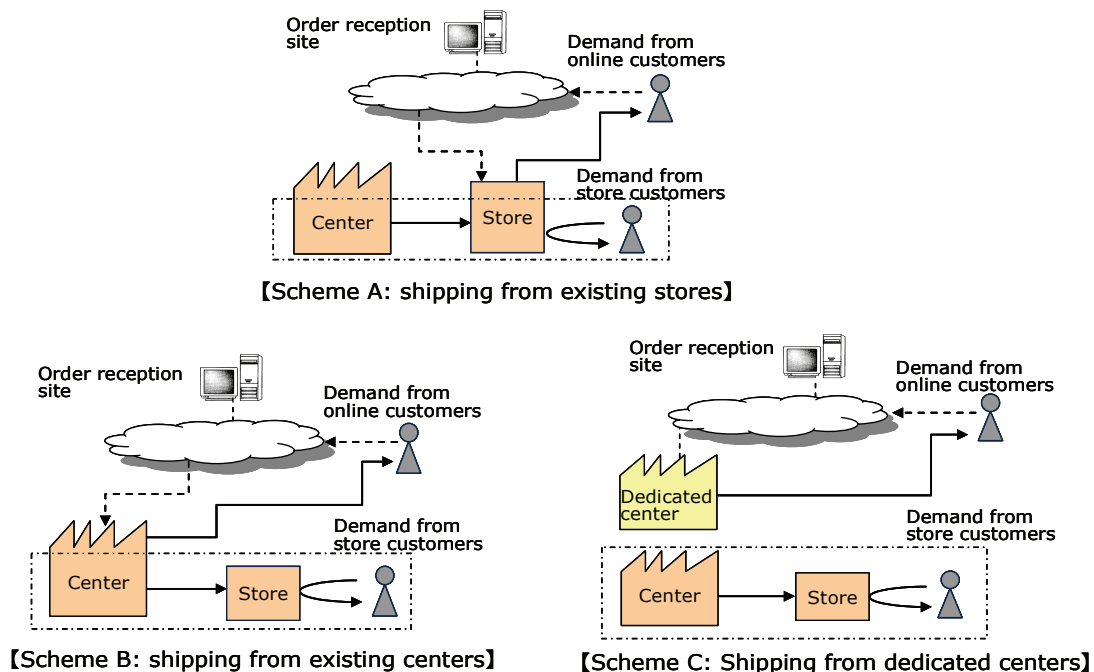


Fig. 1 Three shipping schemes for online supermarkets subject to our evaluation terms of the total volume of stock.

## EVALUATION OF STOCK CHARACTERISTICS

In the following, the stock characteristics of the three schemes shown in **Fig. 1** are evaluated and compared using simulation.

### Evaluation model

To simplify the evaluation, we focus on a single product (e.g., an item of fresh food) for which there is demand every day. Generally, there may be a number of distribution centers and each center may serve a number of stores. However, since our objective is to understand the basic differences between the different schemes, we will consider the simplest case, which can normally be seen at the launch of an online supermarket, i.e., a case with a single distribution center and a single store. The stock for store customers is naturally held at both the distribution center and the store. The stock for online customers is kept at both the distribution center and the store in Scheme A, but at the distribution center or centers alone in Schemes B and C. The lead time, which is the time from the reception of an order to the shipping of the ordered goods, is zero for store customers because there is no need to pack and deliver the goods. On the other hand, online customers are bound to experience a certain lead time, which includes the time needed for picking and packing the ordered goods but also a certain waiting time to accumulate orders to avoid the inefficiency of shipping goods each time an order is placed. In other words, orders from each online customer are accumulated up to the end of a certain time interval, and all the goods ordered by this customer during this period are shipped together. Although we assume that goods are delivered in the manner of traveling salesman, the manner of delivery is not of concern in this paper because our objective is to evaluate the stock characteristics.

### Numerical assumptions

(1) It is assumed that the number of items bought by store customers per hour is normally distributed with the average being 5 and the standard deviation 20%, and that

the distribution of the demand from online customers is the same as that of items bought by store customers.

(2) On the basis of actual data for some existing online supermarkets, we assume that goods are shipped from each center or store every 3 hours.(3) Stock is replenished in the manner shown in **Table 2**. Considering the ease of handling orders for restocking from the store, we assume that the distribution center delivers restocking goods periodically at intervals of 6 hours. The lead time for the center to ship goods to the store is 5 hours. Manufacturers/suppliers replenish stocks in the center based on a predefined stock threshold for each product. In other words, restocking is not done at regular, set times. The lead time from the detection of the depletion below threshold of the stock of a product to the shipping of the restocking product is 2 hours. The initial volume of stock and the size of quantity used for restocking in the center(s), and the equivalent values for the store, are the minimum values that we found from a

Table 2 Numerical data used for the evaluation of each scheme

Shipping scheme	A: Shipping from existing store		B: Shipping from existing center		C: Shipping from dedicated center		
Facility	Existing center	Existing store	Existing center	Existing store	Dedicated center	Existing center	Existing store
Initial stock (No. of items)	60	120	60	60	35	35	60
Restocking scheme	Threshold-based restocking. -If No. of stocked items is no greater than 60, 40 items are added. -Lead time of restocking is 2 hours	Periodic restocking. -Restocked every 6 hours so that 120 items will be stocked. -Lead time of restocking is 5 hours	Threshold-based restocking. -If No. of stocked items is no greater than 60, 40 items are added. -Lead time of restocking is 2 hours	Periodic restocking. -Restocked every 6 hours so that 60 items will be stocked. -Lead time of restocking is 5 hours	Threshold-based restocking. -If No. of stocked items is no greater than 30, 30 items are added. -Lead time of restocking is 2 hours	Threshold-based restocking. -If No. of stocked items is no greater than 30, 30 items are added. -Lead time of restocking is 2 hours	Periodic restocking. -Restocked every 6 hours so that 60 items will be stocked. -Lead time of restocking is 5 hours

preliminary simulation could avoid the occurrence of an out-of-stock situation.

## EVALUATION RESULTS AND DISCUSSIONS

Assuming that demand arises stably over time, we have executed simulation for 96 business hours of the online supermarket.

### Comparison between Schemes A and B

Simulation results for Schemes A and B are shown in **Table 3**. The variations in the volume of stock in the store, that in the center, and the total volume over time are shown in **Fig. 2**. The cumulative value for each of these over the simulation period is shown in **Fig. 3**. This signifies how long products are kept in stock.

In both schemes, the store is restocked every 6 hours. **Fig. 2 a)** shows that the stock in the store is larger in Scheme A than in Scheme B. This is because Scheme A requires the store stock to meet demand from both store customers and online customers, and consequently the size of restocking for the store to avoid an out-of-stock situation needs to be higher than in Scheme B, which requires the stock to satisfy demand from store customers only. As shown in **Fig. 2 b)**, in Scheme A, the center is restocked every 6 hours because it needs only to restock the store. In Scheme B, on the other hand, the center is restocked slightly more frequently because it needs to ship goods every 3 hours for online customers in addition to restocking the store every 6 hours. In both schemes, the center is restocked based on the same criteria as shown in **Table 2**, and it needs to meet demand from both the store and online customers. From **Fig. 2 b)**, it is difficult to determine which scheme requires a larger stock, and so, we look at **Fig. 3**, which shows the cumulative volume of stock. The cumulative stock in the center is slightly larger in

Table 3 Example of evaluation using simulation (Schemes A and B)

Item		Scheme A: Shipping from existing store	Scheme B: Shipping from existing center
Total stock over 96 hours		8021	6898
	Total stock in store	3626	2059
	Total stock in center	4395	4839
No. of restocking events	To store	15	15
	To center	20	22
No. of occasions of being out of stock (and No. of items)	Store	4 (5+10+11+2=28 items)	5 (3+1+3+2+1=10 items)
	Center	0	0

Note: Restocking lead time from order from store to delivery to store = 5 hours.

Scheme B because the center needs to ship goods to online customers. However, the total stock of the center and the store is smaller in Scheme B. This is because the difference between the two schemes in the volume of stock in the store is greater than that for stock in the center. Thus, overall, Scheme B is more advantageous than Scheme A.

**Comparison between Schemes B and C**

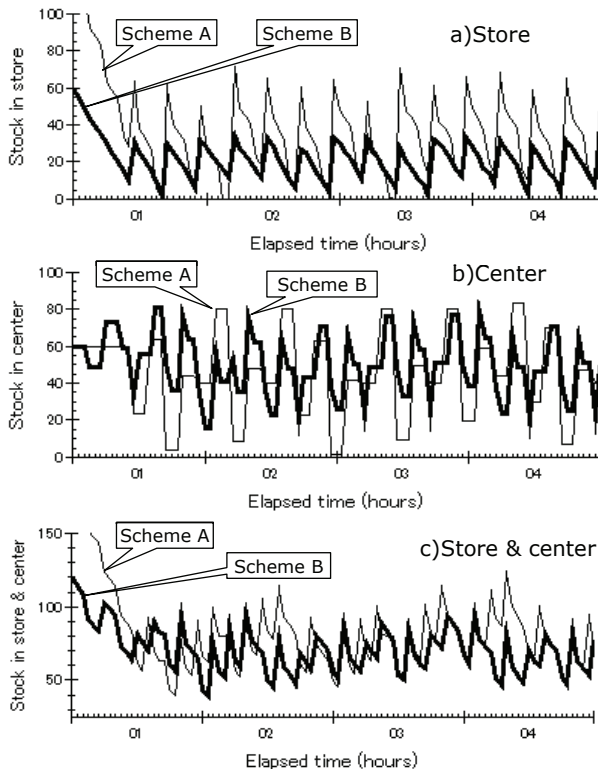


Fig. 2 Change in stock over time

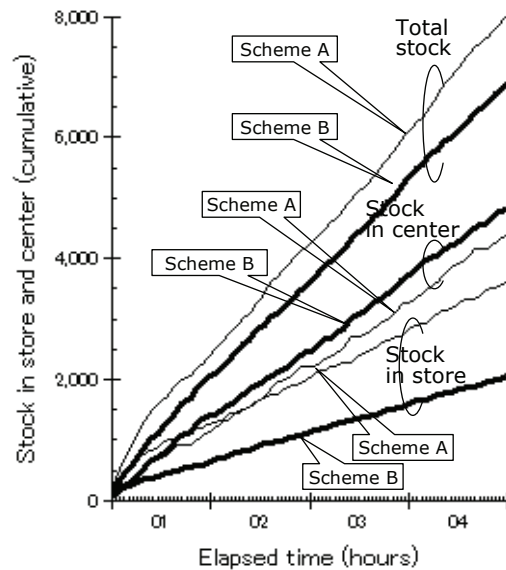


Fig. 3 Change in cumulative stock over time

**Table 4** shows simulation results for Schemes B and C. The variation in the volume of stock in the store, that in the center, and the total volume over time are shown in **Fig. 4**. The cumulative value for each of these over the simulation period is shown in **Fig. 5**.

Table 4 Example of evaluation using simulation (Schemes B and C)

Item		Scheme B: Shipping from existing center	Scheme C: Shipping from dedicated center
Total stock over 96 hours		6898	8208
	Total stock in store	2059	2059
	Total stock in existing center	4839	3201
	Total stock in dedicated center	-	2948
No. of restocking events	To store	15	15
	To existing center	22	14
	To dedicated center	-	15
No. of occasions of being out of stock (and No. of items)	Store	5 (3+1+3+2+1=10 items)	5 (3+1+3+2+1=10 items)
	Center	0	0

Note: Restocking lead time from order from store to delivery to store = 5 hours.

**Fig. 4** shows that, for both schemes, the change in the volume of stock in the store is the same as that for Scheme B in **Fig. 2**. This means that the difference in the use of the center between the two shipping-from-center schemes does not affect the volume of stock in the store. The volume of stock in the center shown in **Figs. 4 b) and 4 c)** for Scheme C is the total of the stock in the existing center and that in the center dedicated to online sales. The volume of stock for Scheme B is smaller than that for Scheme C. This reflects the well-known characteristics that the volume of stock needed to cover variations in the total demand from both store customers and online customers (as in

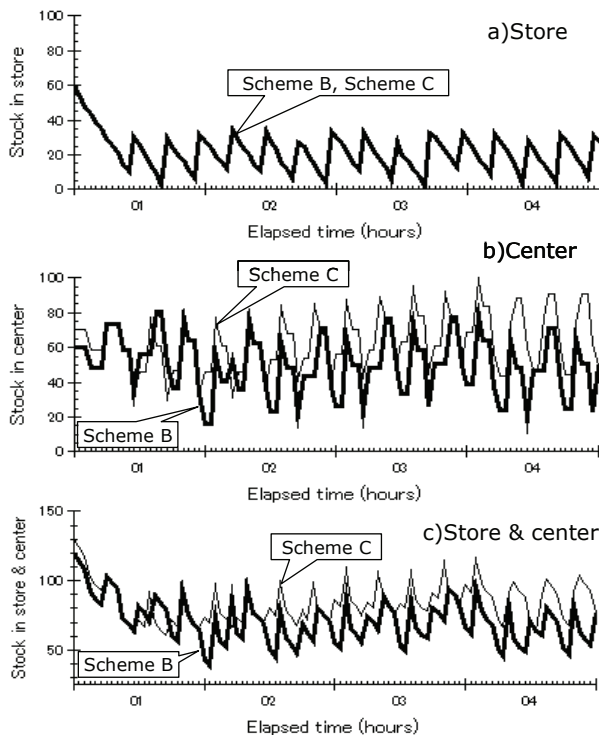


Fig. 4 Change in stock over time

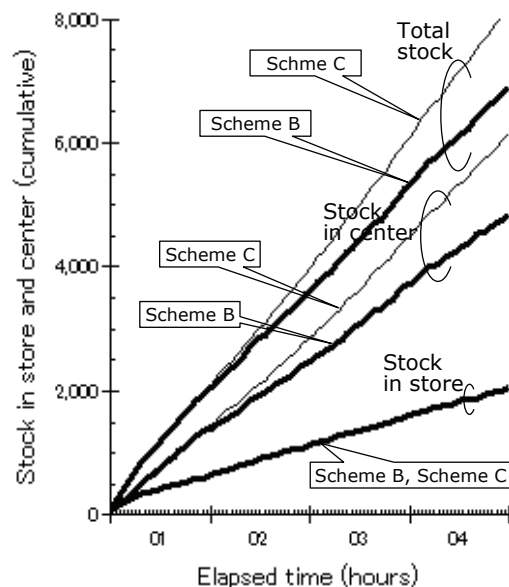


Fig. 5 Change in cumulative stock over time

Scheme B) is smaller than the volume of stock needed to cover the variation of the



demand from store customers and that from online customers separately (as in Scheme C). This is also evident in **Fig. 4 c)** and in the cumulative value, shown in **Fig. 5**.

This is the reason why the total volume of stock in Scheme B is smaller than that of Scheme C in **Table 4**.

So, we can conclude that, from the perspective of the volume of stock, Scheme B is the one to be preferred among the three schemes.

### Discussions for extended cases

So far, we have focused on a simple case where there is only one center (or two centers in the case of Scheme C) and only one store, and, in particular, where the distributions of the demand from store customers and that of the demand from online customers are exactly the same. An actual supermarket is more likely to have more than one center and more than one store. However, even in such a complex case, the relationships between the three schemes (Schemes A, B and C shown in **Fig. 1**) in terms of the volume of stock will not be different from those of the above simple case. Scheme A always needs to have a larger stock than Scheme B because it requires both the center and the store to keep stock to meet the demand from online customers. The larger the number of stores, the greater the difference in the volume of stock between the two schemes becomes. In the comparison between Schemes B and C, the latter is less desirable because it requires two separate centers, each holding stock. The difference between the two schemes in the volume of total stock widens as the number of stores increases.

As an example of a complex case, we have simulated, over a period of 96 business hours, a case where there is one center (or two centers in Scheme C) and 3 stores, and the demand from store customers is the same as that in the evaluation described above but the demand from online customers is twice as large. The simulation result shows that the total volumes of stock of Schemes A, B and C, are 28,222, 10,918, and 18,720, respectively(see **Fig. 6**). Scheme B required the smallest stock.

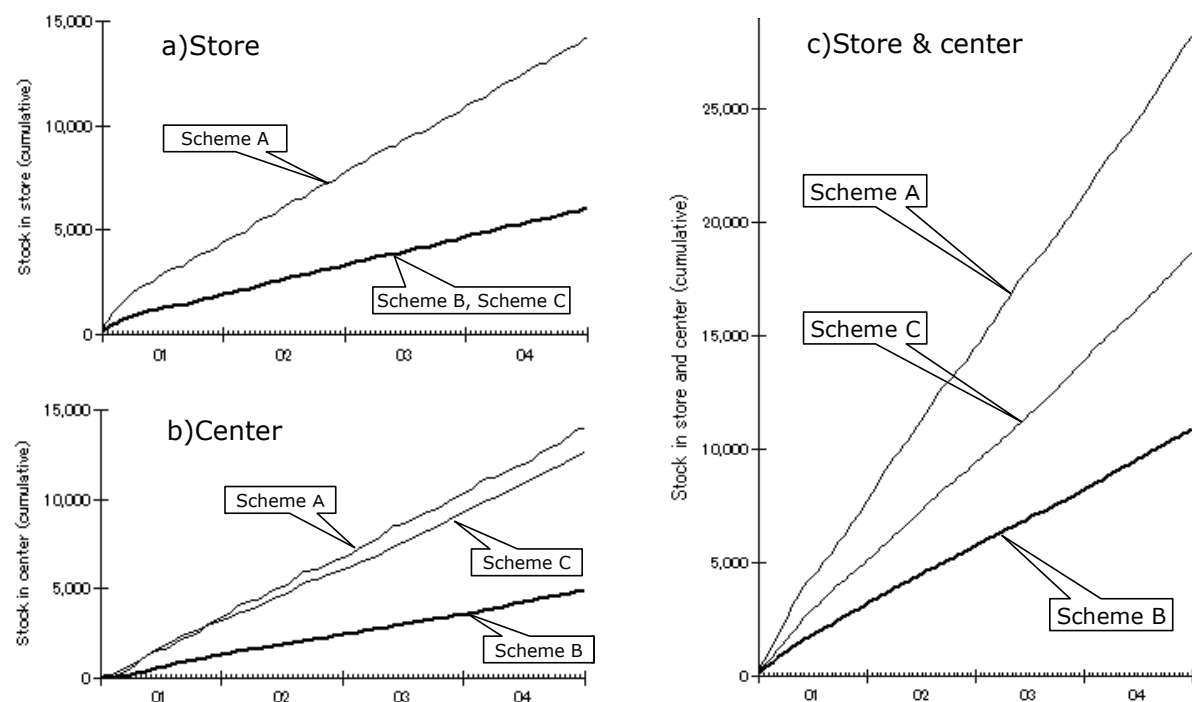


Fig. 6 Change in cumulative stock over time for the case "1 center+3 stores"

In addition to varying the number of stores, it will be necessary to conduct further evaluation by varying the distribution and the average of the demands, the restocking scheme, the order timing (whether all stores request restocking at the same time or at different times), lead times, etc. It is expected that the differences between the three schemes in terms of the total volume of stock will widen as the ratio of the demand from online customers to the total demand increases. As the lead time for delivery from the center to stores increases, the difference between Schemes A and B or that between Schemes B and C will widen. It will be necessary to confirm these trends qualitatively.

## **CONCLUSIONS**

We have considered a supermarket that sells goods both in real stores and online, and compared different strategies for shipping goods to online customers. Specifically, we first compared the volumes of stock of two shipping schemes. Scheme A makes good use of the existing facilities by shipping goods to online customers from stores. In Scheme B, the center ships goods to online customers. We have then compared Scheme B with Scheme C, which uses a separate center to ship goods to online customers. It has been found qualitatively that Scheme B, which holds stock in a smaller number of locations for a shorter length of time, requires a smaller stock than Scheme A. It has also been shown qualitatively that Scheme B, in which the stock at the center is used to meet both the demand from the stores and the demand from online customers, requires a smaller stock than Scheme C. So, from the perspective of the required volume of stock, Scheme B, the scheme of using an existing center to ship goods to both stores and online customers, is the most advantageous.

Supermarkets that offer online sales also need to consider the cost of delivering goods to online customers, in addition to the cost of stock. If they choose to expand the service area of their online sales in a bid to increase the potential demand, the cost of delivery will increase. To improve profitability, they need to reduce the delivery cost by optimizing the shipping intervals and the manner of delivery. So, the future thrust of our study will be to investigate how to improve the efficiency of delivering goods to online customers.

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# ENTERPRISE MODEL FOR RISK MANAGEMENT IN TURNKEY POWER PLANT PROJECTS

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## **I. Introduction**

Plant projects, for instance power plant projects, are complex endeavors. The turnkey EPC-contractor (*Engineer-Procure-Construct*) is fully responsible for the supply chain of the scope of supply and services within a network of sub-suppliers and sub-contractors. In general, the value added by the EPC contractor is merely between 15 and 25% of the overall project value [1].

Fossil fuel fired power plant projects could have a contract value of more than 700 million Euro and a realization time of more than 2 years [2]. The network of sub-suppliers and sub-contractors usually consists of more than 100 parties which have to be managed and integrated for realization by the EPC-contractor. Liquidated damages for delays or for deviations to performance data are commonly stipulated in the EPC contract. For instance, a 100,000€ contractual penalty per day for delaying the date of taking into operation is as a realistic assumption in power plant business. Hence, dealing with risks is a key competence of the EPC-contractor to complete a plant in time and budget.

Risk management is a commonly discussed topic in literature, however, empirical studies show that it lacks of integrated and applicable methods and tools in practice [3]. In the field of plant engineering special attention has to be drawn that the methods and tools of risk management have to be aligned with the level of information available along the project cycle. In the context of an EPC-contractor, the complexity of a power plant is a key driver for the total project risk and could be used as an indicator for risk management.

This paper presents an enterprise model for risk management which defines the structure and behavior of risk management and contains methods and tools which are applicable in practice. The remainder of the paper is organized as follows: In section II the theoretical basis of risk management and enterprise models are analyzed in brief. In section III the enterprise model for risk management is presented. In section IV the results of the enterprise model are summarized and future work is reflected.

## **II. Theoretical Basis**

Risks are uncertain events or conditions that probably might occur in a project and could have a negative effect on objectives [4]. Risks can be evaluated by the combination of the consequence of the event and the likelihood of their occurrence. Risk management is the systematic application of management policies, procedures and practices to the task of establishing the context, risk identification, risk analysis, risk evaluation, control/treatment and communication of risks in a way that will enable organizations to minimize loss and maximize opportunity in a cost-effective way [5]. The risk management process is standardized and shows a high level of consensus [4, 5, 6, 7]. Risk management is an iterative process consisting basically of risk identification, risk analysis, risk evaluation, risk treatment and monitoring/controlling of risks. Depending on the reliability of information given in the course of a project the qualitative, semi-quantitative or quantitative risk evaluation could be performed [8]. With regard to project risks the project risk management (PRM) could be defined as an integral part of project management [9].

An enterprise model is an abstraction (generalization) that represents an enterprise as a system with its relevant elements and their relationships and shows how it is organized and operated [10]. An enterprise model is used to improve the effectiveness and efficiency of the enterprise. In the context of enterprise models a reference model provides information which could be used for modeling specific models (specialization) or

for adaption and application in projects. For modeling, informational, functional, organizational, and resource views are used depending on the objective and the perception of the modeler [11]. A combination of the informational and functional view is of primary importance in representing the structure and behavior of a system with regard to completeness, consistency and integratability [10]. For enterprise modeling, object-oriented and process-oriented modeling notations are used (e.g. UML Unified Modeling Language, graphs/nets and BPMN Business Process Model and Notation or process chains).

### III. Enterprise model for risk management

With regard to plant projects, most risks are basically determined in the turnkey contract. Hence, PRM is most crucial within the tendering stage. In this stage the PRM has to give a decision support for the prioritization of projects and to derive a proper risk contingency in case of working out an offer. Therefore, the enterprise model is focussing on the PRM within the tendering stage.

#### Modeling approach

The enterprise model consists of two partial models (general model and reference model) which are in a kind-of hierarchy relationship. The general model represents enterprises in plant business and defines the structure and behaviour of risk management in the notation of a UML class diagram in an informational view. The reference model is a specialization of the general model and represents the PRM of enterprises in power plant business. The reference model presents the PRM as a process with methods and tools during the tendering stage in the notation of BPMN in a functional view.

#### General model

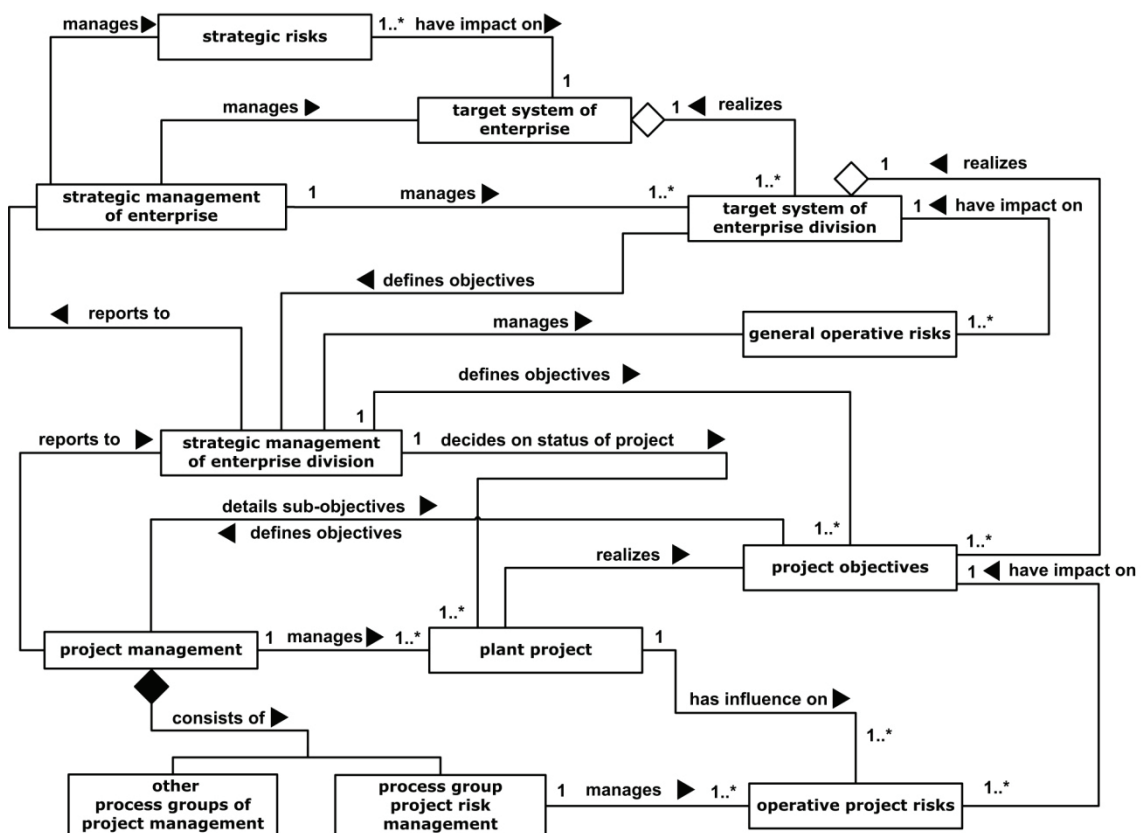


Figure 5: General model of risk management (UML class diagram)

The structure of the risks classes with the respective target systems and management elements is a hierarchy with 3 levels: the operative project risks, the general operative risks and the strategic risks. The operative project risks result from the respective single

plant project, the general operative risks from the support processes of the enterprise and the strategic risks from the strategic processes and the environment of the enterprise. Each risk class has an impact directly on the respective target system. The PRM as part of the project management is related to the operative project risks which could have an impact on the project objectives (performance/quality, cost and time).

The class of the operative project risks is extended by a class diagram of a risk breakdown structure (UML inheritance) [6, 9]. The risk breakdown structure gives a framework of risk categories and sub-categories for systematic risk identification and ensures coverage of all types of risks.

Besides the class diagram of risk management the general model contains a separate risk model for quantitative risk evaluation in a functional view. This risk model defines the process steps of risk evaluation. In the first step, the consequence of a project risk could either be evaluated in terms of cost or time. Hence, a project risk that could have an impact on the performance/quality of the plant has to be evaluated in cost and/or time. In the next step, the time related project risks have to be related to activities in the project schedule and analyzed by critical path method. The aggregation of the time related project risks indicates the risk of a total project delay. The total risk of project delay is converted to a cost related risk by the contractual penalty rate. Finally, all cost related project risks are aggregated to the total project risk. The total project risk (costs) could be analyzed and used to derive the proper level of risk contingency in the offer.

In general, the risk evaluation of a project risk could be done either by a deterministic estimation or by a probability distribution [12]. For instance, a deterministic risk evaluation could be done by a Three-point estimate (Beta distribution/PERT analysis). In this case, the risk aggregation is the sum of the project risks. For the risk aggregation of project risks evaluated by probability distributions, simulation methods (e.g. Monte Carlo Simulation) are required [9]. The selection of the method depends highly on the reliability of the given data, the attitude of the stakeholders, the effort and the expertise of the risk analyst.

### **Reference model**

The reference model represents the PRM process within the tendering stage of (fossil fuel fired) power plant projects. The tendering stage is given with five phases: clarification of the inquiry (1), bid evaluation (2), firm bid preparation (3), negotiation (4) and project evaluation & hand over to order processing stage (5).

The PRM is shown as a process group within the process model of project management [13]. The PRM consists of 11 process steps in the given phases (1-5): check criteria for exclusion (1), check coverage within product configuration (1), plan PRM (2), analyze stakeholder/project environment (2), check criteria for exclusion (repeated) (2), check coverage within product configuration (repeated) (2), semi-quantitative risk evaluation on basis of pre-defined risk categories (2), risk identification (3), quantitative risk evaluation (3), risk aggregation (3) and risk response planning (3).

Within the process model an approach to analyze the product configuration in the PRM is given. The coverage within the product configuration refers to the product complexity of a power plant as an indicator of the total project risk. The product complexity could be described by the product structure. The product structure shows the amount of functional systems in the horizontal dimension and the amount of components/parts of a system in the vertical dimension. For the EPC-contractors of (fossil fuel fired) power plants the product strategy of mass customization has a high significance. Therefore, the EPC-contractors usually pre-define modules on the basis of modular design which could be used in various customer configurations/plant variants. Hence, both individual customer requirements could be fulfilled and cost effects be gained by standardization.

A module could be classified with regard to its grade of standardization. A detailed pre-designed module (type 1 – white box) is fully specified for manufacturing/procurement with detailed documentation available and could be re-used in a plant project without major adaption. A basically pre-designed module (type 2 – black box) is specified with regard to functionality and interfaces and has a basic documentation available. In case of a re-use (coverage) within a plant project configuration, a detail engineering of this module is required. Besides the pre-engineered modules which could be re-used, the

customers usually demand functionalities which are not pre-defined within modular design yet. These functionalities have to be clarified and designed within the plant project as new modules (type 3).

The distribution of the module types within the product configuration could be used as an indicator for the product complexity and within PRM for a qualitative evaluation of the total project risk.

#### **IV. Conclusions and prospects**

The general model represents the risk classes, the target systems and the management elements and defines the structure of risk management for EPC-contractor enterprises. For the quantitative risk evaluation the procedure of evaluating and aggregating project risks to the cumulative cost related total project risk was developed.

The reference model gives a process model. The process steps of PRM are described in detail with regard to input, output, recommended methods and tools. Within this process model an approach for a qualitative risk analysis of the total project risk by analyzing the product configuration is presented. This approach for PRM combines risk management with complexity management.

The enterprise model could be used to derive enterprise specific models or to extract, adapt and apply contents directly within PRM. The reference model was validated in a case study of power plant projects with regard to applicability and acceptance of the process steps, methods and tools in practice.

Future work could to be done to integrate an organizational view for risk management in the enterprise model. With regard to the reference model the possibility of an extension for additional types of plants could be analyzed.

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## **A FRAMEWORK FOR SUPPLY CHAIN RISKS**

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### **ABSTRACT**

The current supply chain risk frameworks are generally constructed according to the direct potential risks faced by a supply chain member in terms of supply, internal process, and demand, e.g. Chopra and Sodhi (2004), and Tang (2006). This type of framework ignores the risks propagated from other directly affected sources, e.g. Hopp et al. (2008). Our paper proposes a supply chain risk framework that considers both direct and indirect disruptions. Further, three levels of impacts forged by the risks are identified: macro, industry, and supply chain. New types of risks e.g. relationship risk, proximity risk, and substitution risk are included as an extension of our risk framework.

**Keywords:** supply chain risk, supply chain framework

### **INTRODUCTION**

The supply chain network is often a complex network of business entities involving upstream and downstream flows of products and/or services, along with the related financial flows and information. It becomes more complex due to the adoption of contemporary practices such as lean initiatives, just-in-time sourcing, globalization, outsourcing, multi-tiered partners, coordination, and sustainability. The benefits to these new practices are significant but the increased supply chain complexity, emphasis on efficiency, extended coordination with external stakeholders also suffer from vulnerability, especially, when disasters or economic crises seem to occur with a greater frequency recently.

We hypothesize that the efforts from a single company in the context of a network is far from enough to cover it from many risks, especially those passed down from other companies, or those from risk reactions of a competitor. Chopra and Sodhi (2004) identified nine risk types. Almost of all of them are direct risks to the focal company and belong to three different groups: sourcing, internal process, and demand. Tang (2006) broadly divided supply chain risks into operational and disruption risks. The operational risks are the inherent uncertainties in customer demand, supply, and cost. Disruption risks are those caused by natural and man-made disasters, or economic crises.

A novel framework of supply chain risks could be developed to cover the above possible types of risks to help companies systematically identify their potential risks. In the following sections, the framework is proposed and several indirect risks are identified.

### **SUPPLY CHAIN RISK FRAMEWORK**

The framework proposed here extends the framework of Chopra and Sodhi (2004) into three levels: supply chain, cross supply chain/industrial, and macro levels.

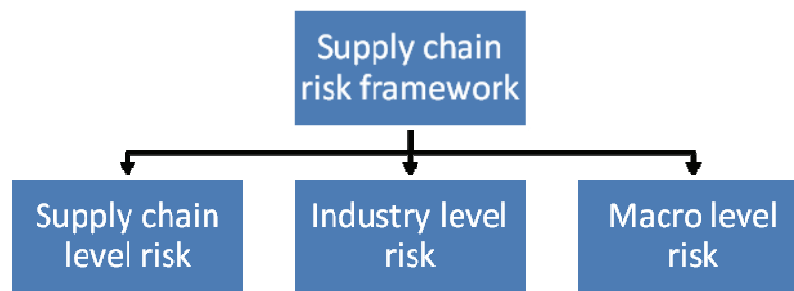


Figure 6. Supply chain risk characterization framework

Risks at the supply chain level refer to the risks occurring within the supply chain of a focal company. Risks at the industry level are those occurring in the common resources shared by supply chains of different focal companies in the same industry. Risks at the macro level can affect and disrupt facilities simultaneously across the supply chains of different industries (Figure 6).

#### **NEW RISKS IDENTIFIED AT EACH LEVEL**

We identify several indirect risks at the three risk levels. An indirect risk refers to the disruption from the source which is not directly linked to the focal company but affects it through risk propagation or interaction of the risk reactions of entities within or outside the focal company's supply chain.

##### **A. Indirect risks at the supply chain level**

Three indirect risks at the supply chain level are explained: proximity, tier, and relationship risks.

**Proximity risk** refers to the risk from the geographic distance of a focal company's suppliers, which may be located within the same disaster zone. In the case of a disaster, those suppliers may fail to provide materials at the same time and thus causing supply shortage to the focal company.

**Tier risk** refers to the risk brought out not by the focal company's first tier partners but by its tier 2 or greater partners due to single sourcing or proximity risks. For example, the Japan Triple Disaster in 2011 put Apple at risk through its Tier 4 supplier, EElectrotechno (Mitsubishi Gas Chemical Sub), which provided BT resin to Apple's Tier 3 suppliers but was hit by the disaster at Fukushima. At the time just, before the disaster, EElectrotechno in Fukushima produced about 50% of the global BT resin supply.

**Relationship risk** originates from the gap between a supply chain entity's actual importance and its assumed importance to its partner. For example, there are four types of supplier relationship (Bensaou, 1999) according to the investment in the relationship by a buyer and a supplier: captive buyer, strategic partnership, market exchange, and



captive supplier (Figure 7). If a buyer thinks that its supplier is a captive supplier to itself (e.g. the buyer is more important to the supplier than vice versa) while the fact is that its supplier is only a market exchange partner to the buyer, the misconception will cause the buyer trouble when a disruption occurs and the supplier can easily cease supplying.

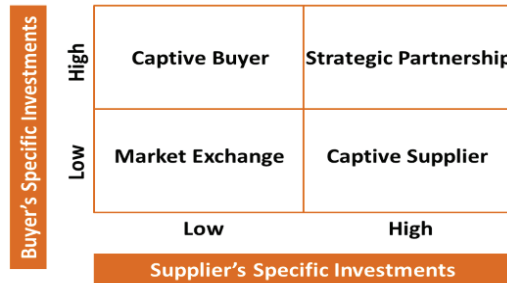


Figure 7. Types of buyer-supplier relationship (Bensaou, 1999)

The mitigation of relationship risk requires a supplier/buyer's pre-disruption preparation and post-disruption reactions. Pre-disruption preparation includes the investment in the relationship to change the buyer-supplier relationship profile. However, the final relationship may not be decided by only one side as the other side may at the same time change its status or investment in the relationship. For example, although Google may wish its Google Map application to be continuously used in the iPad and iPhone, Apple prefers to have its own map application in its latest launch of iPhone 5.

**B. Indirect risks at the industrial level**

Two indirect risks at the supply chain level are identified: competitive and cluster substitution risks.

**Competitive risk**

In Figure 8, both plants  $P_1$  and  $P_2$  source materials from the same supplier  $S_{1,1}$ . After a disruption, supplier  $S_{1,1}$  is no longer able to provide supply to plants  $P_1$  and  $P_2$ . As the result, two plants have to turn to an alternative supplier, say, supplier  $S_{1,2}$ .

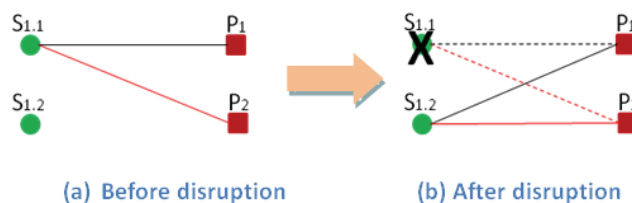


Figure 8 Competitive risk

This is a moot point if  $S_{1,2}$  has enough capacity to meet both  $P_1$  and  $P_2$ 's demands. However, if  $S_{1,2}$  has only limited capacity, according to Hopp *et al.* (2008), the following factors may influence  $S_{1,2}$ 's decision of who to provide supply: plant size, willingness to pay, plant preparedness, business history, contractual agreements, first-come-first-

served, and market share of  $P_1$  and  $P_2$ . On the other hand, when a plant can secure supply from  $S_{1,2}$ , it still needs to decide the amount of supply according to its competitive strategy. An extreme example could be that the plant accepts all the supply that  $S_{1,2}$  can provide to starve its competitor. In so doing, the plant may have to pay a holding cost incurred by an unnecessary portion of supply.

This is exactly what Nokia did when its supplier, a Philips semiconductor plant in Albuquerque, New Mexico, was hit by a lightning bolt in March 2000. The lightning created a 10-minute blaze that contaminated millions of chips and subsequently delayed deliveries to its two largest customers — Finland's Nokia and Sweden's Ericsson. Nokia reacted promptly and swept all available supply from other suppliers. The net result was that Ericsson reported a \$400 million loss because it did not receive chip deliveries from the Philips plant in a timely manner and could not find alternative suppliers, which had been taken by Nokia (Sheffi and Rice, 2005).

Thus, a competitive risk is triggered by the failure of  $S_{1,1}$  to supply  $P_1$  and  $P_2$ . The risk is industry wide as entities  $P_1$ ,  $P_2$  and  $S_{1,2}$  may not be in the same supply chain. The impact of competitive risk on  $P_1$  and  $P_2$  is decided by 1) the relative competitiveness of  $P_1$  and  $P_2$  in the view of  $S_{1,2}$ , 2) the relative promptness of  $P_1$  and  $P_2$  reacting to the risk, and 3) the purchasing plan of  $P_1$  (or  $P_2$ ) to secure supply from  $S_{1,2}$  based on its own capability and its understanding of  $P_2$  (or  $P_1$ ).

### **Cluster substitution risk**

A cluster is a geographical concentration of organizations in certain interconnected industrial groups tied by competitive pressure to form collaborative and competitive relationships. The Californian wine cluster, Italian leather goods cluster, fashion cluster in France, Silicon Valley in the US, software outsourcing in India, automotive cluster in Thailand and logistics clusters in Germany and Netherlands are some examples.

Although a cluster has its own advantages such as inclusion, collaboration, cooperation for its participants, it is also subject to risks such as natural disasters or substitution by other clusters. Cluster substitution risk is an expansion of competitive risk as more competitors are looking for alternative suppliers. However, the interaction among the competitors are similar to those in the mitigation for competitive risk.

The severe Bangkok flood of October 2011 exposed the hard disc drive (HDD) cluster to the significant risk of substitution. The worst flooding in 50 years left production facilities of Western Digital, Hitachi Global Storage Technologies, Seagate, and suppliers of HDD manufacturers like Nidec submerged under water. The damaged production and inventory led to a global HDD shortage and consequently a price hike. Once manufacturers or suppliers in the disaster-prone cluster can find safer alternative locations with similar operational environments, the potential risk of cluster substitution may become a reality.

### **C. Indirect risks at the macro level**

The direct risks at the macro level can include natural disasters (e.g. earthquake, tsunami, flood, volcano), economic instability (e.g. GDP swings and economic crisis or recession), terrorist attacks, social condition, or contagious diseases. As a macro level risk generally hits multiple facilities and impacts multiple types of flows (material, finance, information) crossing multiple industries simultaneously. The indirect risks at the macro level are actually the complicated combination of indirect risks in both the supply chain and the industrial levels such as proximity, tier, relationship, competitive, and cluster substitution risks.

Generally, for a focal company, the recovery from disruptions depends on the company's ability to find back-up capacity in the supply chain before its inventory is used up. This back-up capacity has either been built beforehand as the focal company's effort to build resilience into its supply chain or just exists across supply chains as the excess capacity of other entities. However, the overall back-up capacity generally is not enough to cover the losses as disruptions by definition belong to the type of risk that is not fully prepared by supply chain entities. Thus companies will fight for the scarce back-up resources and the results will depend on 1) the ability to sense the disruption and react promptly, 2) pre-deployment of resources and relationship with the other supply chain partners, and 3) comparative competitiveness in the interaction with others in a disruption.

Thus, it is necessary for a company to know the disruption propagation/cascading effects and understand the effects of the interaction among the supply chain entities both before and upon the occurrence of a disruption.

### **CONCLUSION**

In the current study, a supply chain risk framework with three levels: supply chain, industry, and macro has been proposed. It differentiates direct and indirect risks for a focal company at each level. Subsequently, several new types of risks such as proximity, tier, relationship, competitive, cluster substitution risks are identified as an extension to the traditional risk framework. We believe this framework can enable a company to have a broader view of identifying potential risks. Further, more new risks can be identified according to this framework.

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## **SUPPLY CHAIN RISK MANAGEMENT IN INDIA – PRACTICAL INSIGHTS**

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### **ABSTRACT**

This study is a progression of the paper by Srivastava et al (2012) that investigated key risk management issues affecting Indian supply chains. Here, by using the supply chain risks as identified in the ISL 2012 paper as a start point, we carried out a survey of Indian supply chain professionals to further understand the risks in a practical context. This enabled us to quantify each of the risk factors (low, high or moderate) and gain deeper insights into how practitioners perceive these risks can be tackled. To achieve this, we developed a semi-structured questionnaire, based on the existing literature and initial findings to obtain information from Indian supply chain professionals. This information was statistically analyzed using SPSS and among other things revealed that approximately 50% of organizations did not have supply chain risk management plans per se. Major issues highlighted by the professionals included poor understanding of the project, unclear strategic planning and lack of appropriate IT. Furthermore, natural disaster-, cultural- and forecasting-related risks were key risk management areas. Suggestions for improved risk management included better integration of information systems, freer flow of information and senior management support to improve the current status of supply chain networks in their companies. Incentive-based strategies such as contract-linked rewards were proposed. Additional suggestions centred around the proportional sharing of risks, costs and benefits to encourage suppliers and other supply chain stakeholders to actively implement supply chain risk management strategies.

### **INTRODUCTION**

Having an efficient and effective supply chain is seen as a leading factor for competitive advantage (Li *et al.*, 2006; Childerhouse *et al.*, 2003). Within this, managing the risks inherent within supply chains is a key activity. Organizations that outsource most of their activities are particularly vulnerable to supply chain risk. Major companies such as Nokia (Li *et al.*, 2006) and Ericsson (Norrman and Jansson, 2004) have realized the importance of implementing supply chain risk measures, only after suffering serious disruptions in their supply chains. As organizations are under constant pressure to achieve positive financial results they are highly incentivised to adopt optimization techniques to make their supply chains efficient and competitive. The costs associated with implementing risk management practices into a company's main objectives are clear, but the potential tangible benefits are seen as unclear and hard to measure (Hendricks and Singhal, 2005). In order for companies to harness the growing opportunities presented by the

internationalization of Indian business, they need to fully understand the challenges and corresponding risks. The key drivers that made globalization possible have also favoured business development in India. The evolution towards greater democratic systems and the open market reforms of 1991 (with the corresponding removal of barriers to trade) allowed foreign firms to do serious business in India for the first time (Goyal, 2006). It is also important to obtain first mover advantages to be ahead of the competition (Rahman and Bhattacharyya, 2003). The Indian market is not only attractive because of its large and increasingly prosperous customer base, but also as it is increasingly a location for high quality (owing to the availability of a highly educated workforce) and low cost (plenty of them) resources (Rienda *et al.*, 2011).

However, as is well documented, India still has significant problems in terms of infrastructure (especially in rural areas). This situation is slowly improving, particularly now that communications, power, electricity and airlines are starting to be privatized. Generally speaking Indian supply chains have many tiers of distribution (e.g. with very few large scale third party logistics providers), which increases the complexity and hence the risk of supply chain failures. For example, transportation of commercial goods is mainly carried out by small logistic operators who typically run only 2-3 vehicles each. This has worked well for the domestic market because most retail outlets in India are small to medium sized. In a move towards market liberalization, in November 2011, the Indian government announced that it would open up the retail market to foreign retailers (such as Wal-Mart, Carrefour and Metro). This liberalization was intended to provide major opportunities in terms of infrastructure investments. However, following substantial street protests, the decision was postponed.

### **RESEARCH OBJECTIVES**

The aim of this study is to quantify the significance of supply chain risks and evaluate current SCRM practices and issues faced by supply chain professionals in an Indian context. The specific objectives are as follows:

- To quantify the significance of supply chain risk based on data analysed from a practitioner based survey
- To elicit information from supply chain professionals regarding their views on implementing supply chain risk management measures
- To identify ways to assist organizations in managing supply chain risk

### **RESEARCH METHODOLOGY**

Based on our previous review of supply chain risk (by regions), a comprehensive survey questionnaire was constructed to capture a qualitative response of the supply chain risk management practices in Indian organizations. The survey was constructed to quantify the extent of various risks (such as economic, labour, infrastructure, legal, cultural), as well as identify major problems and suggestions from the perspective of supply chain professionals. We targeted key stakeholders along the supply chain such as third party logistic service providers, end users and inventory managers as shown in Table 1. The survey questionnaire was distributed at a Confederation of Indian Industries (CII) supply chain conference that consisted of participants representing a range of upstream and downstream supply chain stakeholders. In this way we were able to capture insights on current supply chain risk management practices. The questionnaire was based on a 7 point Likert scale, with possible responses ranging from "extremely low" to "extremely high". Additional questionnaires of the same survey were also emailed to the CII community but response rate was very low. The questionnaire was based on the supply chain risk factors as identified by the literature review (Srivastava *et al.*, 2012). The main aim of this study was to bridge the gap between the theoretical viewpoints of supply chain risk management and the actual status of the risk management practices (in an Indian context). We received 60 completed questionnaires to analyse. Although a higher number would have been desirable, the minimum sample size required to obtain a clear, recognizable factor pattern is reported as 50 by Arrindell and Ende (1985).

Third Party Logistics Provider	17.8%
End User	8.2%
Executive	2.7%
Material/Supply Chain Manager	30.1%
Production	1.4%
Inventory Control	6.8%
System Analyst	2.7%
Support	11.0%
Plant/Operation Manager	9.6%
Purchasing Manager/Buyer	1.4%
Others	8.2%
	<b>100.0%</b>

Table 1. Participant profile

## DATA ANALYSIS AND DISCUSSION

The survey responses were analyzed using SPSS 19. Prior to data analysis the suitability of the survey data was checked for exploratory factor analysis as shown in Table 2. Cronbach's alpha test was applied to measure the internal consistency of the items and coefficient alpha was found to be 0.863. This is in accordance with the minimum acceptable criterion of coefficient alpha of 0.7 (Churchill, 1979). We performed an exploratory factor analysis to obtain the influence of each supply chain risk by using the principal component method with varimax rotation and Kaiser normalization. Higher loadings depict a higher correlation between the variable and the factor. Items with an Eigen value greater than 1 were used in the analysis as well as items with loadings of less than 0.40 were removed. The data were further tested using KMO and Bartlett's test (McDonald, 1981; Hattie, 1985). The results are shown in Table 1. Large KMO values (ideally greater than 0.5) can be used to explain correlations between pairs of variables. Bartlett's test checks correlations between variables and a significance level of *less than .05* is required to carry out a reliable factor analysis. Our results satisfy both conditions. The data set was further tested using *coefficient theta* ( $\theta$ ) which is closely related to coefficient alpha ( $\alpha$ ) and based on the assumption that the first factor to be extracted accounts for the largest proportion of the variance. It is calculated using the formula:

$$\theta = \left( \frac{n}{n-1} \right) \left( 1 - \frac{1}{\lambda} \right)$$

Where  $n$  = number of items in the scale, and  $\lambda$  = the first (largest) Eigen value. The largest Eigen value for our analysis was 4.8 and we have 11 items (11 risk factors). For this data set, coefficient theta was found to be 0.870, which is approaching the desired value. These values are shown in Table 2.

Kaiser-Meyer-Olkin Statistics	0.776
Bartlett's Test Statistics Significance	0.000
Cronbach's alpha	0.863
Coefficient theta	0.870

Table 2. KMO, Bartlett's, alpha and theta results

Table 3 shows the Community values which explains the proportion of variance accounted for by the common factors (or 'communality') of a variable. Communalities value close to 1 show that common factors explain all the variance. Our rotation extraction analysis result shows high values which further support the factor analysis.

<b>Factors</b>	<b>Initial</b>	<b>Extraction</b>
Operational	1.000	0.540
Infrastructure	1.000	0.738
Legal	1.000	0.725
Cultural	1.000	0.653
Economic	1.000	0.553
Supplier	1.000	0.660
Forecasting	1.000	0.598
Warehouse	1.000	0.643
Transportation	1.000	0.572
Labour	1.000	0.566
Natural Disaster	1.000	0.873

*Table 3. Communalities*

Table 4 and 5 presents rotated component results and the initial solution with Eigen values in decreasing order respectively. It shows cumulative variance of 64.741% which means that factor analysis is satisfactory. We have done 3 component factor analyses since Eigen value for component 4 is less than 1. Any 'factor' that has an Eigen value of less than one does not have enough total variance explained to represent a unique factor, and is therefore disregarded. The result of three factor analysis is shown in Table 4. Factor loading is usually taken as correlation between factors and variables and used to decide which variable belongs to which factor. It is clear that maximum factors belong to component 1 followed by component 2 and 3. Therefore we have summarized three most influential risk factors based on their loading; natural disaster, cultural and forecasting as shown in Table 6.

<b>Factors</b>	<b>Component</b>		
	<b>1</b>	<b>2</b>	<b>3</b>
Operational		.680	
Infrastructure		.768	
Legal		.760	
Cultural		<b>.805</b>	
Economic	.721		
Supplier	.744		
Forecasting	<b>.769</b>		
Warehouse	.505		.562
Transportation	.597		
Labour	.467	.425	.409
Natural Disaster			<b>.922</b>

*Extraction Method: Principal Component Anallyis. Rotation Method: Varimax with Kaiser Normalization*

*Table 4. Rotated Component Matrixa*

Component	Initial Eigen values		Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings			
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
<b>1</b>	<b>4.804</b>	43.671	43.671	4.804	43.671	43.671	2.774	25.216	25.216
<b>2</b>	<b>1.299</b>	11.812	55.482	1.299	11.812	55.482	2.756	25.052	50.268
<b>3</b>	<b>1.019</b>	9.261	64.743	1.019	9.261	64.743	1.592	14.475	64.743
4	.906	8.236	72.979						
5	.787	7.158	80.136						
6	.558	5.077	85.213						
7	.459	4.174	89.387						
8	.434	3.941	93.328						
9	.328	2.979	96.307						
10	.224	2.034	98.341						
11	.182	1.659	100.000						

Extraction Method: Principal Component Analysis

Table 5. Total Variance Explained



<b>Risk Factors</b>	<b>Loading</b>	<b>Priority</b>
Natural Disaster	0.922	1
Cultural	0.805	2
Forecasting	0.769	3

*Table 6. The three most influential SC risk factors*

The second part of the questionnaire involved eliciting information from supply chain professionals regarding supply chain risk management practices in their organization (if any). It was not too surprising (and in line with our preliminary study) to learn that approximately half of the respondents reported no current supply chain risk management practices in their organizations. Table 7 shows the respondents opinions on the reasons for this, highlighting that 26.9% of the respondents consider that there is no clear understanding of supply chain risk management concepts within their organization. Another important factor appears to be an unclear strategic plan (so no provision for clear and well defined risk mitigation practices in the event of unforeseen circumstances). The other important factors were inappropriate organization to support a risk management system, lack of commitment of partners and inappropriate technology to support supply chain risk management. This is in agreement to our previous findings that SCRM practices in India generally are seen as informal and reactive, rather than proactive.

Poor understanding of the concept	26.9%
Unclear strategic plan	18.3%
Inappropriate organization to support a SCRM system	12.5%
Low commitment of partners	12.5%
Lack of appropriate IT	12.5%

*Table 7. Top five problems in implementation of supply chain risk management*

We were interested to determine the type of collaborative planning (if any) an organization supports as part of their supply chain activities. This could be in a forecasting, capacity, inventory or production context. We found that over 17% of organizations support all four types of capacity planning, while almost 14% of organizations did not have any type of capacity planning at all. As shown in Table 7, collaborative capacity planning was the most popular (nearly 22%), followed by production planning (17%).

Collaborative capacity planning	21.9%
Collaborative production planning	17.2%
Collaborative inventory planning	12.5%
Collaborative forecasting	12.5%

*Table 8. Top capacity planning activities*

We further asked for recommendation to improve supply chain risk management in their organizations. As shown in Table 9, top management support and integrated information system were the preferred choices, followed by free flow of information, training and

closer collaboration between the demand and supply segments of the supply chain network.

Top management support	17.8%
Integrated information system	17.8%
Free flow of information	17.1%
Human resource training	12.4%
Closer link between demand and supply	11.6%

*Table 9. Top five recommendations from supply chain professionals*

The respondents were also questioned regarding incentive schemes used to motivate various segments of supply chain network. Here and as shown in Table 10, we found sharing of risk, cost and benefit was most highly rated. This was followed by contract and information based incentives to keep the supply chain network intact and up to date.

Equal sharing of risk, cost and benefit	34.2%
Contract based incentives	23.7%
Information based incentives	18.4%
Trust and relationship based	7.9%

*Table 10. Incentives to promote supply chain risk management practices*

Additional information and 'war stories' were gained from several of the respondents who elaborated on their individual experiences and concerns. For example one small size enterprise recently adopted a proactive SCM approach as an important aspect of their business. This helped them – among other things - to gain better visibility of hidden costs. Another respondent (in the manufacturing sector) reported difficulties in managing public opinion when a road accident had taken place near to their manufacturing site. Although the accident had nothing to do with the company, the firm had to provide compensation to the victims in order to alleviate public concern. This was an unforeseen environmental risk. Other issues included uncertainties in demand, high response demand (while switching over to large scale operations in a short time period), labour unions, theft and pilferage, racism, lack of influence/empowerment at a decision making level (e.g. suggestions to speed up internal processes were not taken on board), and the classic – 'lack of communication'. Risks are generally managed by planning ahead whether this is for capacity, demand, and inventory or for infrastructure related purposes (or similar).

The supply chain in India is overly-dependent on road and rail. The Western Dedicated Freight Corridor will not be commissioned until 2017 (at the earliest). Until then the lack of freight train capacity, poor road conditions and inadequate use of IT will continue to adversely affect supply chain efficiency. Some Indian organisations are managing risk in a proactive manner. For example, Mumbai Air Cargo Terminal has a capable risk management system that systematically covers procedural aspects such as safety and security, as well as IT systems. This enables them to address most unforeseen incidents in a timely manner.

As discussed in this paper, the results of our survey reinforced that infrastructure was an ongoing major supply chain risk issue, but cultural-related, as well as natural disaster-related risks are high certain industry sectors. This is especially the case in those that

are located away from cities such as mining and agriculture where the population and workforce is rural.

## **CONCLUSIONS**

The findings reported in this paper is based a semi-structured questionnaire to obtain information from Indian supply chain professionals. The analysis revealed that approximately 50% of organizations did not have supply chain risk management strategy or plan for managing potential risk in their supply chains. Our findings highlight that many organisations have poor understanding of the project, unclear strategic planning and lack of appropriate IT. Furthermore, natural disaster-, cultural- and forecasting-related risk were key risk management areas. Suggestions for improved risk management included better integration of information systems, freer flow of information and senior management support to improve the current status of supply chain networks in their companies. Incentive-based strategies such as contract-linked rewards were proposed. Additional suggestions centred around the proportional sharing of risks, costs and benefits to encourage suppliers and other supply chain stakeholders to actively implement supply chain risk management strategies. The authors acknowledge that whilst the findings are interesting and noteworthy, several limitations remain. For instance further work is required to dissect the findings of this study and establish a detailed understanding of current practices and their impact in supply chain risk management strategies within an Indian context and how this compares with other countries. It would also be useful to discover the degree and nature of the risk management component within the Indian supply chain, if this was part of a bigger global supply chain.

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## **RISK-ORIENTED DECISION SUPPORT IN SENSITIVE LOGISTICS NODES**

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### **ABSTRACT**

The expected further increase of supply chain risks (see for example Christopher et al. 2004, Wittenbrink 2012) leads to a growing necessity of decision-support for the handling of these risks. Particularly unforeseen risks pose major challenges for supply chains and can result in serious consequences with major economic losses.

To improve the resilience of supply chains against unforeseen risks, our research focuses on the development of a model that offers decision-support in case of a damaging event, thus diminishing the impacts of these events. Therefore, the attention of our research is not limited to a single supply chain but also specifically focuses on sensitive logistics nodes, which unite many supply chains within a geographically bounded area.

**Keywords:** Risk management, decision-support, simulation techniques, freight villages

### **INTRODUCTION**

Risks are part of every business operation and can never be avoided completely. To minimise the danger of corporate crisis, a conscientious and responsible approach to the handling of risks and the resulting impact on business is essential. Particularly the handling of unforeseen risks pose major challenges for supply chains and can result in serious consequences with major economic losses. If such an event occurs, there is no time to analyse processes, to identify the complete range of possible actions or even to estimate and assess the dimension of possible actions. To prevent or at least mitigate possible economic losses, prompt, efficient and high-quality decisions and reactions to occurred risks are important. This is denoted by Mesarović et al. (1970, p. 43) as the fundamental dilemma of decision-making: "on the one hand there is a need to act without delay, while on the other, there is an equally great need to understand the situation better". A preventive decision strategy aimed at coping with damaging events can mitigate this dilemma.

We also follow this approach. The centre of our attention lies upon freight villages as these represent particularly sensitive logistics nodes. They constitute a particular kind of logistics agglomeration and perform important tasks for the supply of goods. Freight villages are characterised by multimodality, multifunctionality and supra-regionality (Aberle 2009). The term multimodality indicates that a freight village combines different modes of transport, normally road and rail, but sometimes also waterborne and air. For this purpose, a terminal of intermodal transport is located in a freight village (Rall 2008). The term multifunctionality describes the variety of transport activities within a freight village and supra-regionality characterises freight villages as a transshipment hub between regional and national transport networks (Wildebrand et al. 2011).

The main objective of our approach is to achieve of a high level of business continuity and increase the resilience of the flow of goods in freight villages after the occurrence of a damaging event. To this end, a simulation model depicting the warehousing, transporting and cargo handling processes within freight villages is used. Decision trees are applied, in order to ensure an efficient utilisation of the simulation model for decision-support in case of a damaging event.

This paper presents the conceptual design of our decision framework.

## **LITERATURE REVIEW**

Managing risks in sensitive logistics nodes after the occurrence of a damaging event has to be handled promptly in order to mitigate the impacts of such risks. To achieve this, different concepts of risk response can be applied after the occurrence of a damaging event (Brühwiler 2011). In the context of risk management literature, the term risk response is defined in a manifold of different ways. Hopp et al. (2012) refer to risk response only as the reaction to occurred risks and define the two strategies detection and speech. The classification from Waters (2011) referring to risk response comprises the following eight risk response strategies: (i) ignorance or acceptance of risks, (ii) reducing the probability of risk, (iii) reducing or limiting the consequences of risks, (iv) transferring, sharing or deflecting the risk, (v) making contingency plans, (vi) adapting to events, (vii) opposing a change and (viii) moving to another environment. These strategies can be partially performed without the occurrence of risks; in this case risk response refers to any potential risk and is defined as the most appropriate way of dealing with all possible risks (Waters 2011). Within this scope, there are further classifications and definitions of the term risk response, see for instance Sudy et al. (2013), Ritchie and Brindley (2009) and Panthi et al. (2007). Besides the diverse perceptions of risk response within the scope of risk management literature, there are also further concepts that deal with the response to risk events. Amongst others these are the concepts of emergency management, crisis management and business continuity management (c.f. Waters 2011). These individual concepts are also defined and distinguished in many different ways. Without dwelling on the different definitions in detail, our understanding of emergency management comprises the recognition of serious risks and the establishment of measures against these risks (BSI 2008). In this context, emergencies are characterised by an abrupt and unforeseen event (Brühwiler 2011), either caused by human hand or through nature, where normal conditions cannot be recovered in an adequate timeframe, the impacts are intolerable (BSI 2008) and responsive actions are required to protect life and property (Bosse and Roy 2009). Emergencies can be extended to crises (BSI 2008), which are described by three typical characteristics: surprising effect, threat pressure and time pressure (Faghfour 2013). Normally, crisis management is applied towards critical situations that cannot be handled with the regular existing operational and organisational structure and can lead to a business crisis (BSI 2008, Heath 2007). It comprises the response to tangible and intangible situations as well as the recovery of an organisation to a previous level of functioning (Heath 2007). Compared to crisis management, business continuity management is focused on the business processes and deals with the quick resumption of business performance and a rapid overcoming of a disruption to resume normal function (Brühwiler 2011).

In this paper, we refer to risk response as a strategy following Hopp et al. (2012). The centre of our attention lies in the impacts of possible risks and the answer to the question of how to react in order to rapidly diminish the negative impacts of these risks. An immediate reaction is also necessary for preventing and minimizing further losses (Bosse and Roy 2009). Risk response not only includes the response after the occurrence of a damaging event, furthermore a preventive examination with possible risks is important in order to anticipate future events. This allows for timely decision-making in the occurrence of a damaging event (Bosse and Roy 2009).

A central problem for decision-making lies in the dynamic corporate environment, which requires particularly rapid reactions and consequently reduces the available time to react. A number of different methodologies are available to support the decision-making

process during risk management after the occurrence of a damaging event; these stem from a multitude of scientific disciplines, for instance operations research, decision theory and statistics (Gluchowski et al. 2008). This paper focuses on risk management decision support with the help of decision theory.

In general, decision-support is defined as taking actions towards the improvement of a decision's efficiency (Pfohl 1977), which means that the quality of a decision is improved and that the effort of making the decision is reduced (Lassmann 2006). A decision is considered to be the result of making a conscious choice as a targeted reaction towards a specific situation. This means that a single alternative is selected from a manifold set of behaviour options under the assumption that the options can be compared in such a way that the outcome of the decision can be evaluated (Pfohl 1977).

In this paper, we will use the term decision-making process as a broader term for the act of making a choice. Generally speaking, the decision-making process consists of decision-making and decision implementation. More specifically, the process can be divided into the phases: intelligence phase, design phase, choice phase, implementation phase and monitoring phase (Heinen 1991).

All phases within the decision-making process are characterised by the fact that they are based around the conscious evaluation of the available information - each phase consists of information collection, information processing and transfer of information (Heinen 1992).

Decision support systems can be applied towards all phases of the decision-making process. However they are particularly relevant during the intelligence phase and the design phase. The intelligence phase is characterised by a severe lack of information; the determination of whether the available information is sufficient to reach a rational decision is subject to the decision-makers individual opinion under increasing time pressure. As such, decisions can only be made intuitively and with a high risk of failure (Gluchowski 2008). To this end, decision support during the intelligence phase particularly focuses on rapidly contributing information relevant to the decisions to be made by providing an enhanced dynamic view on the available data (Klesse et al. 2003). The design phase consists of gathering information regarding the available options and evaluating their possible consequences as well as formulating possible target situations and decision parameters (Heinen 1992). During this phase decision support can be used for modelling purposes, i.e. to utilise the available information to expose previously unknown relationships enabling the creation of complex models. The choice phase is centered on evaluating in how far the identified options can meet the ascertained target situations; the information gained within this process is used to select a specific choice of action. Once an option has been selected, it is applied to reality during the implementation phase, i.e. the conceptual decision alternative is translated into tangible measures (Klesse et al. 2003). The monitoring phase can be considered as the beginning of a new intelligence phase, since the information that is gathered through monitoring the decision implementation progress can be used to incite further decision processes (Heinen 1991).

Our approach aims at accelerating the decision-making process, in the sense of reducing the time it takes to develop an adequate decision. To this end, decision support particularly targets the intelligence phase and the design phase by increasing the speed with which information can be provided and alternate solutions can be assessed. Furthermore decision support is intended to yield solution procedures in preparation towards the actual decision.

## **METHODOLOGY**

A decision is a reaction to a specific situation based on processed information (Pfohl 1977). Prompt allocation and provision of information as well as a suitable preparation and structuring of information enhance the transparency of decision situations. This eases the decision-making in the case of a damaging event and allows for quick, appropriate and systematic decisions to be made. To achieve a high transparency of risk situations and a more comprehensive understanding of risk interdependencies, a

preventive examination of possible risks is important. To support decision-making in the case of damaging events in freight villages, the first step lies in collecting all available information regarding possible risks. Once the information has been gathered, the decision situation and all alternate courses of action can be presented. Subsequently the possible scenarios are created and a simulation of the scenarios and their possible outcomes is performed, thus generating a recommended action strategy. Our methodological approach is shown in Figure 1.

This paper focuses on presenting the decision situation, for this purpose a decision-theoretical methodology is used.

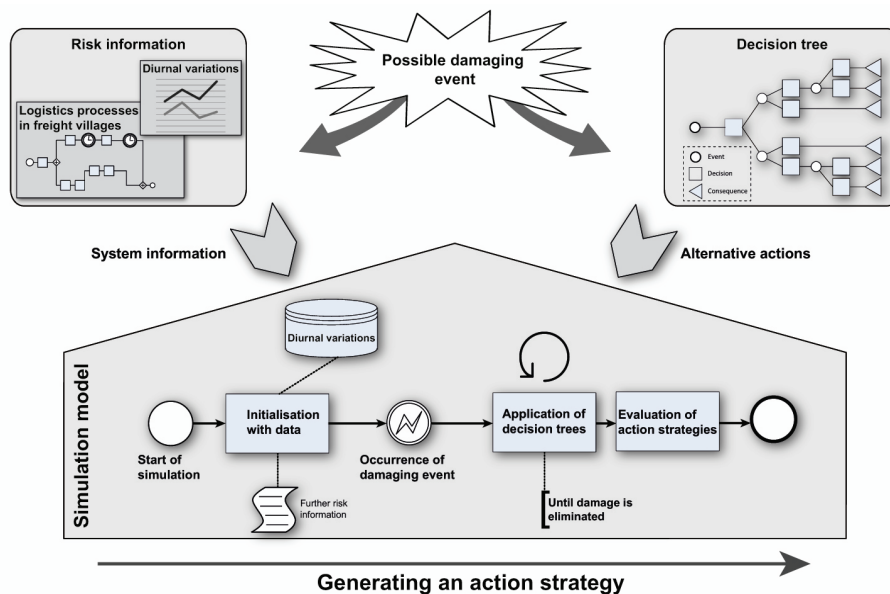


Figure 1: Decision support model for the development of courses of action in case of damaging events

### Risk information

Risk information can be divided into information regarding the modes of transport and the technical infrastructure, as well as the processes and the volume of traffic.

The given situation in freight villages is represented by the transport and technical infrastructure. If a damaging event occurs, it concerns a certain local condition. Therefore, information about the transport and technical infrastructure builds the initial point for further conclusions about the concerned actors, processes and goods. The information regarding transport and technical infrastructure is also essential for the following courses of action.

The warehousing, transporting and cargo handling processes are of high importance for maintaining the flow of goods in freight villages after a damaging event. This results from the circumstance that a damaging event in a freight village immediately interrupts the logistics and transport processes at an operational level. To ensure business process continuity and rapid resumption of business, the business processes must be well known and documented. Therefore, the processes are captured and depicted in a reference model to create improved process transparency. For further explanation see Breuer et al. (2012).

Information about the volume of traffic provides information about the extent of affected goods as a function of the time of day. Subsequently, conclusions can be drawn about the expected degree of capacity utilisation and possible arising bottlenecks. Furthermore detailed information about the importance and handling of the different goods can be made and considered in case of a damaging event.

Knowledge of risk information supports decision-making in the intelligence phase.



## **Decision trees**

Within the scope of the design phase, different means of representation can be used to model a decision problem in a structured fashion. For risk response after damaging events, besides the structuring and modelling of the decision situation, also the generation of an appropriate action strategy to be executed in this situation is necessary. Decision matrices, decision trees and influence diagrams are means of representation that support a comprehensive understanding of a situation and force the decision-maker to clearly and precisely formulate objectives, the alternative actions, the state of the natural surroundings and the consequences caused by a decision (Eisenführ and Weber 2003). Decision matrices and decision trees are very similar in their depicted informational content. Both show the correlations between alternative actions, events and consequences (Jungermann et al. 2005). However, decision trees are more useful for analysing sequential decision problems under uncertainty (Middleton 2007). In contrast, influence diagrams contain less detailed information but give a more general impression of a problem structure and offer high transparency, while the alternative actions for making a decision are not depicted (Eisenführ and Weber 2003).

In case of a damaging event, the environmental circumstances and the whole situation have to be surveyed permanently in order to be able to react if further negative impacts occur and make necessary adjustments in the action strategy. Also the alleviation of bottlenecks as well as the maintenance of business processes has to be ensured. In consideration of these facts, decision trees are applied, because they support the analysis of sequential decision problems and the courses of action are easily readable. Also, the depicted information is more detailed than that contained in influence diagrams (Eisenführ and Weber 2003).

In decision tree diagrams, three kinds of nodes and two kinds of branches are used (Middleton 2007). Decision nodes are depicted as a square and represent a possible decision situation (Laux et al. 2012). Event nodes or chance nodes are symbolised by a circle and characterise the occurrence of possible events (Jungermann et al. 2005). Each consequence represents a combination of certain decisions and states of nature. They are called terminal nodes and are represented as triangles (Middleton 2007). The branches emanating from a decision node symbolise the possible alternative actions available at that point. Branches stemming from a chance node symbolise the possible outcomes of an event that may occur at that point (Jungermann et al. 2005). By traversing the tree, an action strategy can be established from the combination of certain decisions, states of nature and the connections between them.

For each possible risk, a decision tree will be created, which includes the courses of action referring to a particular damaging event. In a next step, the structured information about the alternative actions, the state of the natural surroundings and the consequences of the particular action strategies, depicted in the decision trees, will be implemented in the simulation model, allowing for the action strategies to be assessed.

## **Simulation**

In general, simulation can be used to analyse the relationships between causes and effects of dynamic processes (Kuhn 2008). For our approach, we use a discrete event-driven simulation for analysing dynamic effects of damaging events as damaging events can be easily implemented and triggered by individual simulation runs.

The simulation model is based on the gathered risk information and can be used for the depiction of the relevant warehousing, transporting and cargo handling processes as well as the flow of goods in freight villages. The specific characteristics of the transport and technical infrastructure are also considered and implemented in the simulation model. Therefore, standardised simulation modules that are then adapted as necessary by individual programming to establish capacities and define the specific abilities. To be able

to simulate varying levels of traffic congestion, multiple diurnal variations are taken into account.

The simulation model builds the base for testing the impacts of damaging events and for evaluating possible action strategies as response measures to them. The response measures are based on decision trees. These will be implemented in the simulation model by individual programming and if-else-constructs that take the different events into account.

The combination of risk information, decision trees and simulation model build the decision framework, which can be applied in case of damaging events. In particular, the functionality of decision trees is exemplarily demonstrated for one damaging event, namely the occurrence of damage within the intermodal terminal.

### **APPLICATION**

We aim at achieving a high level of business continuity and securing the flow of goods after the occurrence of a damaging event with the help of decision trees, allowing us to model the decision situation in a structured fashion. Therefore, the first step lies in ascertaining the events and alternative actions.

If a damaging event occurs, the first decision that must be made is whether a reaction to it is necessary or not. Reactions that can be executed for securing the flow of goods are alternative routing or a normal delivery of the goods to the intermodal terminal. When the goods are normally delivered, either a direct turnover or temporary stocking of goods is possible, depending on the extent of damage.

After execution of a certain action, possible events respectively possible states of nature are "improvement of the situation", "no changes" and "further decline of the situation". Improvement of the situation means that business continuity and secured flow of goods are achieved, through the implemented response measures. Currently interdependencies and domino effects between different kinds of damaging events are not regarded. If there is no improvement of the situation in spite of response measures after an appropriate timeframe, further actions respectively the perpetuation of adapted measures has to be made. The return to usual business activity is possible by situation recovery. It is further assumed, that once a situation has been improved, it will not relapse back into a negative state. A part of the developed decision tree, assuming that reactions are undertaken, is shown in Figure 2. Thus, two stages of decisions are considered.

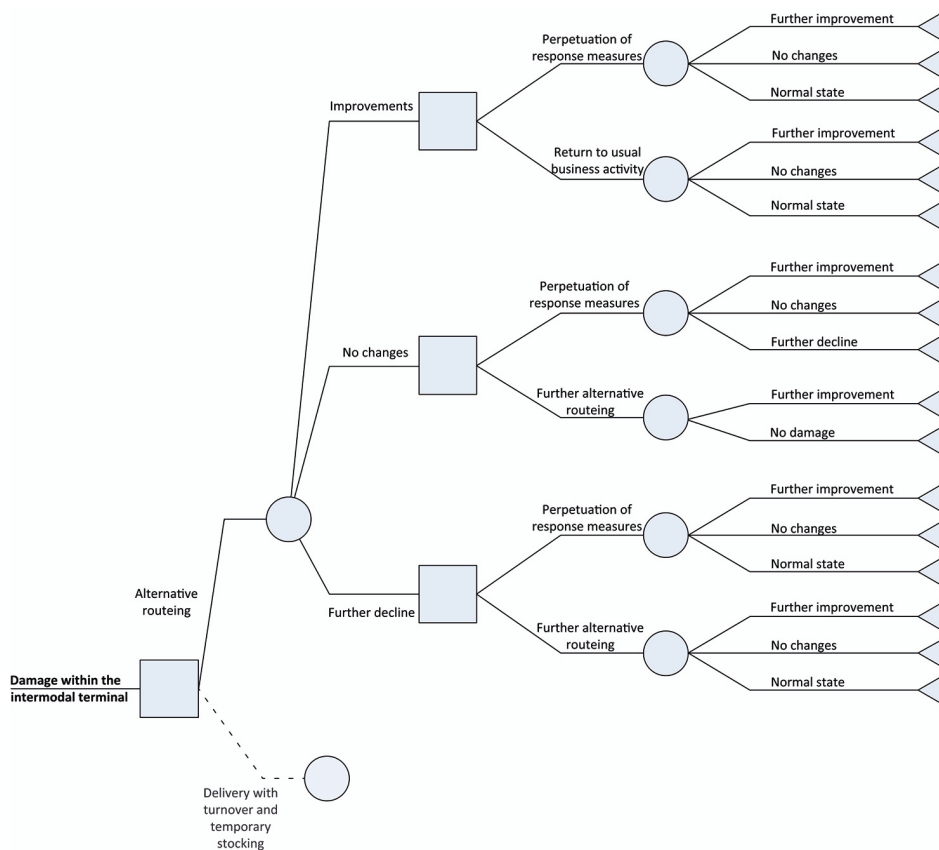


Figure 2: Decision tree for damaging events in intermodal terminals

In the decision tree, multiple action strategies can be identified: the strategy “alternative routing” in combination with the “perpetuation of response measures” in spite of a situation improvement, leads to further situation improvements in terms of securing the flow of goods or even to return to the normal state.

The choice of a course of action depends on further conditions like duration and the effective date of a damaging event as well as the extent of capacity losses. These conditions are considered in the simulation. Through implementing the decision tree in the simulation model, the assessment of the individual action strategies as well as the generation of a recommended action strategy through simulation is possible.

## CONCLUSION

The purpose of our research is the support of decision-making in freight villages thus improving their resilience towards unforeseen risks. To achieve a high level of business continuity and ensure the flow of goods after the occurrence of a damaging event, a rapid reaction to such an event is necessary. A rapid reaction is supported by a quick and structured provision of information in a time-critical situation, which accelerates the decision-making and enhances the decision quality (Gluchowski 2008).

Hence, in this paper, the focus lies on the conceptual design of a decision framework with an emphasis on the application of decision trees. These are used for modelling the decision situation in a structured fashion and also for providing information in case of a damaging event. Generated action strategies distribute the remaining available capacities in such a manner that the flow of goods can be secured in case of a damaging

event. The functionality of decision trees has been exemplarily demonstrated for a damaging event within the intermodal terminal.

In a next step the implementation of decision trees in the simulation model for evaluating the action strategies by simulation will be performed. Furthermore, an appropriate timeframe in order to review the adapted response measures has to be defined. Also, interdependencies between different risks and domino effects have to be elaborated and considered in the decision trees as well as in the simulation.

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# **HOW TO IMPLEMENT SUPPLY CHAIN RISK MANAGEMENT? AN EMPIRICAL ANALYSIS WITHIN THE MEDICAL TECHNOLOGY INDUSTRY SECTOR**

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## **ABSTRACT**

While different aspects of internal risk management in companies have been discussed in literature intensively, an analysis of the organisational implementation of supply chain risk management (SCRM) remains elusive. Existing SCRM concepts do not sufficiently consider situational factors such as the limited resources of small and medium-sized companies. Thus, the aim of this paper is to develop a conceptual framework for the organisational implementation of SCRM that includes situational factors. A literature review, case studies and a workshop are the basis for the developed approach for implementing SCRM.

## **INTRODUCTION**

The term supply chain management (SCM) is widely discussed both in academia and practice. Early discussions about the term focused on the management of inventory (Houlihan 1987). Due to on-going outsourcing activities and the concentration of core competencies, the understanding of SCM has been broadened. Christopher defined it as *"the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole"* (2005, p. 5).

Managers within the medical technology industry are faced with complex and multi-tier supply chains. Furthermore, Original Equipment Manufacturers (OEM) within these industries source a high proportion of high-tech as well as highly innovative parts, which makes them dependent on their supply networks. In summary, SCM plays a crucial role in the medical technology industry. Today, more than 90,000 employees are working in the medical technology industry in Germany. The companies are specialised in different key technologies and were originally dealing in the metal processing, optical, IT, or electronic sector (Stockhorst 2012). Most of the companies are small and medium-sized enterprises (SME). And only 6.5% of them employ more than 250 skilled personnel. Due to the top export markets like the USA, France, and China, the German export share of 66.2% is relatively high. With a total revenue of 21 billion Euro, achieved in 2011, Germany is ranked third after the USA and Japan in the total revenue of the worldwide medical technology industry (Spectaris 2012).

Products like heart-lung machines, hip-joint prostheses, or artificial cardiac valves show that the German medical technology industry is characterized by a very high product variety (Kramme and Kramme 2011). Moreover, the German law (Medizinproduktegesetz - MPG) defines medical devices as technical products, which tend to treat, monitor, or analyse human ailments (§ 3 Abs. 1 MPG). Therefore, the supply chains within this industry are highly quality driven so that supply chain risks play an important role.

## **SUPPLY CHAIN RISK MANAGEMENT**

Two perspectives of risks can be distinguished. On the one hand, risks follow from the uncertainty of future events. Measurable uncertainty can be characterized as risk in contrast to non-measurable uncertainty (Knight 1921). On the other hand, there exist different approaches which depend on the disciplines. In the context of business economics risk indicates a potential loss or damage. Therefore, it means the opposite of a chance. While in mathematics, risk does not yet contain a value judgement (Diederichs 2004). This paper follows the latter understanding. Hence, supply chain risk is *"the damage – assessed by its probability of occurrence – that is caused by an event within a company, within its supply chain or its environment affecting the business processes of more than one company in the supply chain negatively"* (Kersten et al. 2011, p. 154). Risk may influence the flows of products, services, finance and information.

There exist a large variety of potential risks which may occur. Tummala and Leung (1996) for example differentiate between catastrophic, critical, marginal and negligible risks on the level of hazard severity, while Narasimhan and Sahasranam (2007) distinguish between strategic, tactical and operational risks on the planning level. According to the area of operation, supply, demand, process, control and environmental risks are listed by Christopher and Peck (2004), while supply, production, distribution, financial and personnel risks are named by Rogler (2002) according to the business function.

In order to cope with this large variety of potential supply chain risks, companies should implement a supply chain risk management (SCRM). SCRM *"is to, collaboratively with partners in a supply chain, apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities, or resources in the supply chain"* (Norrman and Lindroth 2004, p. 14).

In general, the SCRM approach follows the same phases' process as risk management. A typical risk management process consists four phases: risk identification, analysis, handling and control (e.g. Terry 1972). In the first phase, all risks must be identified, because only those risks which have been identified can be managed afterwards. During risk analysis, all gathered risks are assessed at first by indicating the likelihood of occurrence and the possible damage. This helps to identify critical risks. Then the risks are prioritized. Risk handling represents the third phase of the risk management process. Here, measures are assigned to each critical risk in order to handle risks targeting at avoiding, reducing, transferring, sharing or taking the risk (Norrman and Lindroth 2004). During the last risk control phase, it is reviewed whether the measures have been applied and if they have been effective. Generally, the risk management process should be repeatedly applied, because risk situation may change over time (Tummala and Leung 1996).

## **APPROACHES OF IMPLEMENTATION**

Implementation can be defined as *"[...] a procedure directed by a manager to install planned change in an organization"* (Nutt 1986, p. 233). This change intends to solve an organisational problem and is required to achieve competitive advantage. The change of

organisational management can be classified into the research field strategic management (e.g. Ansoff et al. 1976). In general, it can be distinguished between a comprehensive and a continuous implementation (Welge and Laham 2012). The comprehensive implementation is addressed by the change management approach, while the continuous implementation is described in process models. In terms of the degree of efficiency, it can be differentiated between global and local change in the context of implementation (Reiß 1995). This paper follows the understanding of a continuous implementation with focus on local change.

The process of implementation can be hindered by several barriers, which could e. g. include cultural, social, organisational, or psychological ones. One possibility to cope with these barriers is to consider situational factors when implementing SCRM (Donaldson 2001). Situational factors, like the company size or the industry classification, are analysed against the background of organisational theories (Kieser 2006).

By including situational factors into the implementation process, different requirements of companies especially in the supply chain context can be considered: e. g. regarding the company size, small companies have a lean organisational structure, clear interfaces and less information which needs to be transferred in contrast to large companies. Therefore, situational factors should be considered when implementing SCRM.

The results of a literature review show that only a few research papers focus on the organisational implementation of SCRM (see table 1). Most of them focus either on certain aspects of SCRM or on SCRM in general. They hardly consider situational factors.

The research questions, whether an internal risk management should be organised centrally or decentrally or whether it should be separated or integrated into an existing organisational structure is e.g. discussed by Burger and Burchart (2002). But they reflect the advantages and disadvantages on a general level and do not consider company-specific factors.

Heusler (2004) writes about the planning, realisation and control of the process of implementation, but he highlights the implementation of SCM and slightly deals with SCRM. Pfohl et al. (2007) oppose the basic problems of the organisational implementation of SCRM on a company level to an organisational implementation on a supply chain level. While they focus on advantages and disadvantages of different organisational aspects, they do not develop concrete recommendations for a companies.

Author	Reference to SCRM	Focusing Implementation
Burger and Burchart (2002)	●	●
Hallikas et al. (2005)	◐	◐
Heusler (2004)	◐	●
Jüttner et al. (2003)	●	◐



Author	Reference to SCRM	Focusing Implementation
Österle and Winter (2003)	○	●
Pfohl et al. (2007)	●	●
Ritchie and Brindley (2004)	◐	◐
Schorcht (2004)	●	●
Winter (2009)	○	●
Zeyer (1996)	○	●

Legend: ● criterion is fulfilled, ◐ criterion is partly fulfilled, ○ criterion is not fulfilled

Table 1: Elements of SCRM and implementation covered by the literature  
Source: based on Schroeder et al. (2013)

A more detailed description about the implementation of SCRM is given by Schorcht (2004). He recommends to introduce SCRM in seven phases from the beginning of the project in phase one until phase seven about the adaption of the model and further development. The concept developed by Schorcht is idealistic and does not include situational factors.

Situational factors are e.g. defined by Ritchie and Brindley (2004) or by Winter (2009), but they do not focus on the implementation of SCRM.

Research articles about the process of implementation mainly focus on other management methods, like e.g. on Business Engineering (Österle and Winter 2003) or on lean management (Zeyer 1996). Thus, it can be summarised, that in research literature there does not exist a conceptual framework for the organisational implementation of SCRM that includes situational factors. The following chapter will describe the research question and design before the conceptual framework will be introduced.

## RESEARCH QUESTION AND DESIGN

Based on the results of the literature review, the authors of this paper strive for a holistic perspective when implementing a SCRM process. Thus, the aim of this paper is to develop a conceptual framework for the organisational implementation of SCRM that includes situational factors. The framework intends to support the decision making process during the four SCRM phases risk identification, analysis, handling and control. For this purpose, the authors conducted four case studies in the medical technology industry to get in-depth insights into the company-specific embodiment of SCRM. The case studies involve qualitative, in-depth analysis of a small set of cases (Ellram, 1996).

From January until April 2013 four semi-structured interviews, lasting between 75-90 minutes each, were conducted with representatives from manufacturing companies of the medical technology sector. Three of the companies were medium-sized and global market leaders for a specific market segment. The respondents had the following positions: manager advanced purchasing, head of procurement department, head of planning global order fulfillment and project manager purchasing.

The conducted case study comprised five parts. The first part dealt with general aspects concerning the company's SCRM. In the second part the organisational implementation of SCRM was discussed. The third part covered the exchange of information within the SCRM process. Moreover, the company's handling with supply chain risk drivers was reflected. At the end, the representatives were asked for giving recommendations.

After the case studies were conducted the authors of the paper organised a workshop in Hamburg, Germany, with 14 experts from manufacturing companies of medical technology industry, wind power industry as well as from logistics service providers and consulting companies. All participants were mainly in leading positions with SCM and/or risk management responsibilities. The aim of the workshop was to find relevant situational factors that should be integrated into the conceptual framework for the SCRM implementation. Here, the results gained in the case studies were deepened. In the following chapter the research findings are described, which results from the case studies and from the workshop.

## **RESEARCH FINDINGS**

First the structural aspects are presented, which result from the cases studies. Afterwards, the situational factors are focused that were deepened during the workshop.

One important topic that was discussed in the case studies was the personnel involvement into the SCRM process. Employees working in the operating divisions along the SC should be integrated into the SCRM process e.g. employees from purchasing, SCM, IT and quality management. Hence, the flow of relevant information is guaranteed. Key benefits of a cross-functional team should be used when composing a SCRM core team. Thus, the hierarchical, functional and also motivational background of the team members as well as their workload and their decision-making power should be considered (see Table 2).

Another topic that was discussed was the embedment of SCRM in the company's structure. SCRM can be embedded as a separate staff unit, integrated into another staff unit, e.g. financial controlling, or it can be embedded as a line function. All organisational forms are connected with different challenges, like e.g. getting the relevant information in time, becoming SCRM-related measures being accepted and applied by the other business units. Beside the support by the management of the company a leader of the SCRM team is needed who coordinates the process, asks for input from team members and who consolidates the topic.

In addition to the organisational implementation it was talked about the interaction with suppliers. Here, the experts mentioned that their suppliers are frequently evaluated. They are e.g. divided into critical and non-critical suppliers depending on their achieved turnover or on the rate of failure. The carefully documentation of rate of failure, numbers of exceptional approvals or delivery delay help to estimate the supplier's situation.

It was also stated that sharing relevant information with the supplier in time, e. g. sales forecasts, or access to relevant data in the ERP system help identifying problems at an early stage.

Aspects of implementation	Key Points from the case studies
Personnel involvement	<ul style="list-style-type: none"> <li>• Team members must be aware of SCRM</li> <li>• Cross functional teams - Employees working in the operating divisions along the supply chain should be integrated e.g. from purchasing, SCM, IT and quality management</li> <li>• Team members must have enough time/capacity for being engaged</li> </ul>
Organisational embedment	<ul style="list-style-type: none"> <li>• SCRM is integrated into another staff unit (purchasing, global distribution fulfillment)</li> <li>• Support by management of the company is needed</li> <li>• A leader is needed who coordinates the process, asks for input from team members and who consolidates the topic</li> </ul>
Interaction with suppliers	<ul style="list-style-type: none"> <li>• Frequent evaluation of suppliers; division into critical suppliers (turnover, rate of failure)</li> <li>• Documentation of rate of failure, numbers of exceptional approvals, delivery delay etc.</li> <li>• Sharing relevant information in time, e.g. sales forecasts, ERP system</li> </ul>
Integration into existing IT-systems	<ul style="list-style-type: none"> <li>• It is helpful if the SCRM process is supported by an IT system</li> <li>• Integration into existing ERP tool is helpful</li> <li>• Supporting by existing SAP or classical workflow-tools seams sometimes to be difficult</li> </ul>
Reporting system	<ul style="list-style-type: none"> <li>• Conducting logistics audits (processes and possible weak points of the suppliers)</li> <li>• Frequency, addresses and volume can support or hinder the outcome of this SCRM phase</li> </ul>

Table 2. Abstract of key results from the case studies

The integration of SCRM into existing IT systems was also discussed. It might be helpful if the SCRM process is supported by an existing IT system, like e.g. ERP system, because the same data can be used for the specific targets. But the support by existing SAP or classical workflow-tools can sometimes also be difficult due to numerous interfaces.

The reporting system was reviewed as well. The frequency, the addressees as well as the volume of the reporting system can support or hinder the outcome of this SCRM phase. Therefore, the used tools should be easily operated and the database maintenance should not be too costly in terms of time (Schroeder et al. 2013).

In addition to structural aspects the integration of situational factors into the SCRM implementation process is determined. During the workshop 31 situational factors were

identified, including multiple references. As situational factors the company size and the complexity of the supply chain network (e. g. number of direct suppliers or customers), the used production technology, existing regulatory frameworks, and knowledge about SCRM have been mentioned from the experts. After identifying relevant situational factors, they were clustered according to the following categories: company, supply chain structure and environment. Factors like branch, business model and company size were allocated to the category company, while vertical integration, single-item production vs. series manufacturing, complexity of the own supply chain, structure of suppliers, interactions, number of partners and cultural factors (country-specific) were summarized in the category supply chain structure. Regulatory framework/laws as well as standards (PMI, ISO 32000) were allocated to the category environment.

### CONCEPTUAL FRAMEWORK

Based on the literature review and the results of the case studies as well as of the workshop, the conceptual framework for the organisational implementation of SCRM should consist of structural and SCRM process-related aspects. In addition, situational factors should be considered (based on Ritchie and Brindley 2004; Winter 2009) (cp. figure 2).

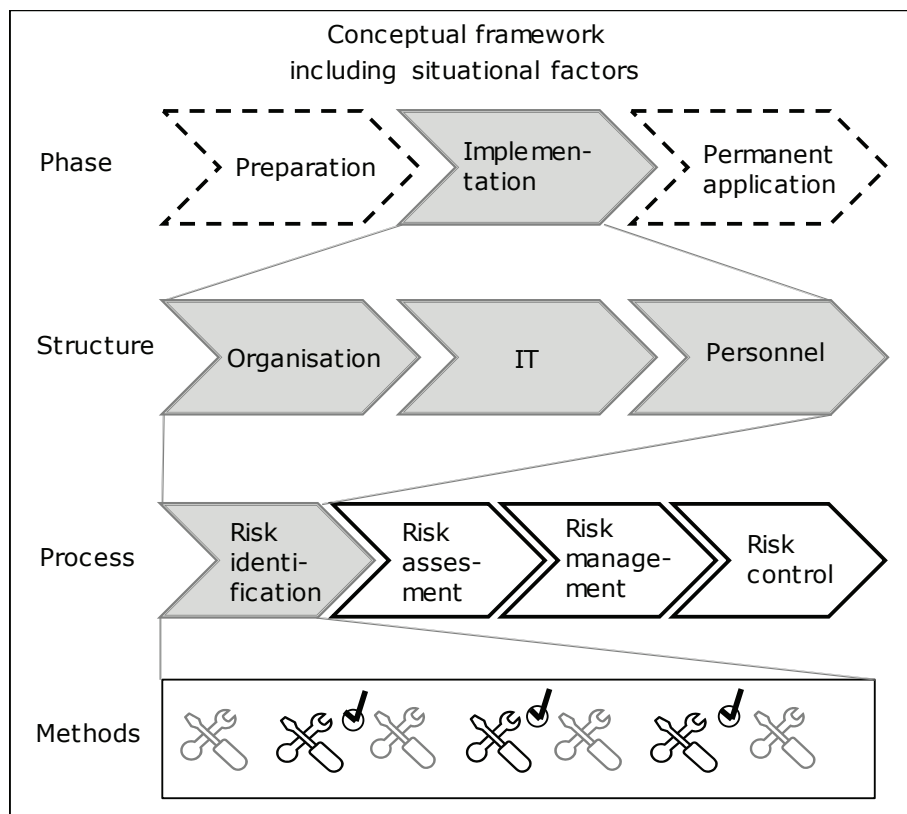


Figure 2. Conceptual framework for the organisational implementation of SCRM

The structural aspects should cover the organisational, technological as well as the personnel implementation (based on Pfohl et al. 2007; Burger and Burchart 2002; Heusler 2004). These structural aspects must be attuned to the different SCRM process phases risk identification, analysis, handling and control. In addition to the structural and SCRM process-related aspects, the authors of the paper compiled catalogues of methods.

Methods and tools were analysed and described which can be used in the different SCRM phase.

Considering the situational factors the framework helps selecting methods that fit best to the company. For example, for the first phase "risk identification" questions how the risk identification process should run, who should be involved into the process or which tools can be used to identify risks must be answered in the beginning. Also the collaboration with internal and external interfaces might influence the results of this SCRM phase. After making decisions for the structural aspects that fit to the company, methods must be chosen to identify risks. E.g. methods like brainstorming, interviews, simulation models etc. can be applied to identify risks. Here, company-specific aspects must be considered. As an example, the use of complex simulation tools to identify risks is not helpful if the company has limited human and financial resources (Schroeder et al. 2013).

The framework intends to support the decision making process during the different SCRM phases. The next step of this research project will be to apply of the conceptual framework for the organisational implementation of SCRM in some of the case study companies in order to evaluate the concept.

## **CONCLUSIONS**

The management of supply chain risks is crucial for the competitiveness of companies within complex supply chains. This is e.g. the case for medical technology enterprises as supply chains in their industry are highly quality driven. Therefore, this industry has been chosen to get insights into the status quo of the implementation of SCRM.

As the process of implementation can be hindered by several barriers, situational factors have been considered. A literature review highlighted that there exists a research gap in this specific field. To address this research gap the authors of this paper conducted four case studies and organised a workshop with 14 industrial experts to develop a conceptual framework for the organisational implementation of SCRM. The framework consists of structural as well as SCRM process-related aspects and considers situational aspects. The organisational, technological and personnel implementation is covered by the structural aspects. In addition, the implementation is supported by the framework by recommending adequate methods for each of the SCRM process phase.

This approach enables decision makers to implement SCRM according to the needs of their company. Nevertheless, the conceptual framework has to be applied to further cases and different industries.

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# SERVICE SUPPLY CHAIN RISK MANAGEMENT

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## 1 INTRODUCTION

Despite the extensive attention received by the traditional manufacturing supply chains, the service supply chains remain less explored (e.g. Sampson and Spring, 2012; Niranja and Weaver, 2011; Sengupta et al., 2006). Lately, some scholars have woken to the situation and called for more contributions in this area (e.g. Ellram et al., 2004; Demirkan and Cheng, 2008). The importance of services has increased during the last few decades, and the transfer from production-based to service-dominant value creation has emphasised the role of the services in the global economy. For example, Spohrer (2010) estimates that the value produced by services will increase to close to 90 per cent of the total value production in the USA by 2050. Considering that the figures were 84 per cent in the 2001 and less than 40 per cent in 1950, this illustrates the growing importance of services to international trade. An understanding of how vulnerable the long and complex international service supply chains can be suggests the importance of proper risk management.

For example, in logistics service provision the amount of knowledge and information required to manage the supply chains and risks involved can be daunting. Training a logistics manager to efficiently manage the operations can take two years (Vilko et al., 2012). Taking into account the complex logistics operations and constantly changing operational environment, it is no wonder supply chain risk management has become one of the important areas of competitive advantage (Sheffi, 2005). Nowadays, as organizations are increasingly extending their reach deeper into the complex and dynamic service supply chains (Mena et al., 2012; Choi and Linton, 2011), they are expected to collectively manage the value provision. Indeed, inter-organizational relationships in supply chains have become increasingly important (Soosay et al., 2008). The level of logistics service provision can determine whether the organization will retain its customers or even attract new ones (Oflac et al., 2012). Thus, information and knowledge play a crucial role in providing services. For example, in the case of supply chain problems investor reactions can be significant, and in such cases shareholder value has been seen to drop by 10 per cent on average (Handfield and McCormack, 2008; Hendricks and Singhal, 2009).

Although the importance of service supply chains has been identified and discussed by several scholars, the specifics of their management have been addressed by relatively few (e.g. Arlbjørn et al., 2011; Baltacioglu et al., 2007; Ellram et al., 2007). The current studies on service supply chains have, so far, focused mainly on applying the existing SCM models to the service context (e.g. Arlbjørn et al., 2011; Baltacioglu et al., 2007; Ellram et al., 2007), while only a few have developed new frameworks for service supply chain management (e.g. Ellram et al., 2004; Baltacioglu et al., 2007). In doing this, some scholars have noticed that the current supply chain management applications do not work well in service management. For example, Cook et al. (2002) identified that traditional supply chain management is not implicit to the service sector practitioners due to the lack of a systematic integration of supply chain functions.

Many studies consider risks to be the main reason why desired performance levels are not achieved in supply chains (e.g., Tummalala and Schoenherr, 2011; Blackhurst et al.,



2005; Swink and Zsidisin, 2006; Craighead et al., 2007; Hendricks et al., 2009). Overall, the understanding of risk management in supply chains is still in its infancy, and further information is needed to bring about understanding of the phenomenon. To address this gap in the current scientific discussion, this study aims to *increase the understanding of the distinctive features of service supply chain risk management by assessing the attributes distinguishing them from traditional supply chain risk management*. In doing this, we build a conceptual framework for service supply chain risk management, which helps to grasp the issue from both theoretical and practitioner perspectives.

The paper begins by describing the related concepts of service supply chain risk management and its distinctive attributes. Next, the conceptual framework will illustrate the special features of the service supply chain in terms of risk management. Finally, the fourth section will conclude the study with theoretical and practical implications, limitations and suggestions for further research.

## **2 RISK MANAGEMENT IN SERVICE SUPPLY CHAINS**

The second section of the study will present the theoretical foundation of the study by first illustrating an overview of traditional (production) supply chain risk management and then looking at service supply chain risk management and its distinctive attributes.

### **2.1 Supply chain risk management**

Supply chain risk management has been increasingly attracting attention from academic researchers. However, for the most part the concepts are still under development, and many of those continue to be without a commonly accepted definition (Vilko et al., 2012).

In order to understand supply chain risk management, it is essential to understand the characteristics of risk. According to Waters (2007) risk in a supply chain is *a threat that something might occur to disrupt normal activities and stop things happening as planned*. A standard formula for (supply chain) risk is (Mitchell, 1995):  $\text{Risk} = P(\text{Loss}) * I(\text{Loss})$ , where risk is defined as the probability (P) of loss and its significance (I).

While supply chain management is the function responsible for the transport and storage of materials on their journey from the original suppliers via intermediate operations to the final customers (Waters, 2007), supply chain risk management aims to identify the potential sources of risk and implement appropriate actions to avoid or contain supply chain vulnerability. Jüttner et al. (2003) define supply chain risk management as: *"the identification and management of risks of the supply chain, through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole"*.

### **2.2 Service supply chain risk management**

As mentioned, work on traditional supply chain management has dominated the academic literature by comparison with work on service supply chains in the past. The topic of service supply chains has received some attention regarding its management frameworks, and as a concept service supply chain management has been defined to include the management of information, processes, capacity, service performance and funds from the earliest supplier to the ultimate customer (e.g. Ellram et al., 2004; Baltacioglu et al., 2007). The benefits that service supply chain management provides can include, for example, better coordination of processes, improved performance

through process integration and improvement of the customer interface (Giannakis, 2011).

According to Arlbjørn et al. (2011), it is important to differentiate the tasks in service supply chain management, which can be achieved through different types of relationships with customers as well as suppliers (Cho et al., 2012). Ellram et al. (2004), list seven theoretical processes of service supply chains, including: information flow; capacity and skills management; demand management; customer relationship management; supplier relationship management; service delivery management; and cash flow. In further developing the Ellram's model Baltacioglu et al. (2007) proposed a service supply chain framework with an application to the healthcare industry to include the following activities: demand management; capacity and resources management; customer relationship management; supplier relationship management; order process management; service performance management; and information and technology management.

More importantly for our case, even less work has been done to investigate service supply chain risk management. The very limited work conducted by academics aimed at understanding the special features of service supply chain risk management can be illustrated by Internet search results for the concept. A search conducted by the authors with *Google Scholar* for "service supply chain risk management" produced only five results, whereas, for example, *Scopus* returned no results. Considering that no proper definition of the concept has been developed and agreed, we utilize these existing definitions:

1) Services supply chain management: *"Management of information, processes, capacity, service performance and funds from the earliest supplier to the ultimate customer"* (Ellram et al., 2004)

2) Supply chain risk management: *"The identification and management of risks of the supply chain, through a co-ordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole"* (Jüttner et al., 2003)

Based on these definitions and the discussion so far, for the purposes of this study, we put forward our own definition of service chain risk management as follows:

*Identification, analysis and mitigation of risks in the service supply chain, involving the whole service supply chain system.*

Our proposed definition takes into account the special systemic nature of service supply chains, where the customers' roles should be considered (Maull et al., 2012) and the overall complexity is higher (Mena et al., 2013). We argue that these issues are integrally linked to the inherent intangibility and to other service-specific features, which we will discuss in detail in the following section.

### **2.3 IHIP attributes and service supply chain risk management**

To gain insight into the distinctive features of service supply chain risk management, we refer to the classical "IHIP" discussion related to services. Service literature has suggested that the distinctive nature of service—In contrast to products—can be connected to the so-called IHIP attributes (intangibility, heterogeneity, inseparability of production and consumption, and perishability, e.g. Zeithaml et al., 1985; Fitzsimmons and Fitzsimmons, 2000; Nijssen et al., 2006). Some criticism and debate has been posed towards generic IHIP attributes, mainly because all services can be claimed to be as different from each other as they are from products (see Lovelock and Gummesson, 2004; Homburg and Fuerst, 2005). However, for the sake of argument and simplicity,

we use these attributes in building a conceptual model for service supply chain risk management.

The first distinctive attribute in services is *intangibility*, which refers to the fact that services do not need to have a physical existence at all (Flipo, 1988; Zeithaml and Bitner, 1996; Bebko, 2000; Grönroos, 2000). The service-delivery process can include tangible elements (as in airlines and hotels), while other services, especially knowledge based ones such as consulting and teaching, are completely intangible (Flipo, 1988; Ritala et al., 2013). This is also reflected in how service-oriented firms utilize much more intangible resources than product-oriented firms (Kianto et al., 2010), and the key assets are the diverse expertise among service personnel and decision makers (Von Nordenflycht, 2010; Jansen et al., 2011). Therefore, both the inputs and outputs of service firms and service supply chains can be considered more intangible than in the case of product-oriented ones.

The second attribute which distinguishes services from products is *heterogeneity*, which shows in both service processes between different firms, and in the variation in the service personnel, customers and customer needs (Edvardsson et al., 2005). In fact, it has been traditionally suggested that service industries are always quite different from each other due to the inherent heterogeneity issues (Lovelock, 1983; Silvestro et al., 1992). Therefore, in service supply chains both the individual actors (and their personnel) as well as the supply chain processes are much more heterogeneous than in product-dominated supply chains. This means that there are no standard inputs or outputs in the supply chain, and therefore there is a major variance in terms of quality, risks and management processes in general. The higher the amount of actors in the whole service supply system, the larger such heterogeneity becomes since there are not only actors that are heterogeneous, but also more idiosyncratic linkages between them.

The third distinctive service attribute is *inseparability*, which refers to the fact that in services, consumption and production take place at the same time due to the dynamic and activity-based nature of services (Edvardsson et al., 2005). Thus, there is a need for collaboration between the provider and the customer in all services, at least to some extent (Tether and Hipp, 2002; Edvardsson et al., 2005). In service and marketing literatures, this has been taken into account in an accumulating discussion on *co-creation*, which refers to the interactive, joint-value creation between customers and providers (Bettencourt et al., 2002; Vargo and Lusch, 2008; Grönroos and Raval, 2011). Furthermore, the more knowledge-intensive and complex the services are, the greater is the need for co-creation to take place (Jaakkola and Halinen, 2006; Ritala et al., 2013). In the service supply chain context, the analysis should take into account the multi-actor value creation system, where co-creation takes place between customers, providers and third party actors such as logistics operators (Maull et al., 2012; Oflac et al., 2012; Mena et al., 2013).

The final generic attribute is *perishability*. It refers to the fact that services are time dependent (Zeithaml et al., 1985; Onkvisit and Shaw, 1991; Grönroos, 2000) and cannot therefore be stored in inventories for later use in a similar sense to products. From a customer perspective, however, service value can be stored in terms of, for example, experiences and other types of value (e.g. Vargo and Lusch, 2004; Edvardsson et al., 2005). This should be recognized in service supply chains, where the customer perspective is highlighted (Ellram et al., 2004). However, perishability remains a relevant issue, especially from risk management perspective. This is because both information and the services themselves are perishable, since knowledge regarding, for example, the operational environment of the service supply chain, is constantly changing and is context- and actor-dependent. This raises challenges in managing and mitigating service supply chain risks.

### 3 CONCEPTUAL FRAMEWORK OF SERVICE SUPPLY CHAIN RISK MANAGEMENT

In their study de Waart and Kemper (2004) highlight the lack of understanding about service supply chains as one of the key issues to master to be able to successfully manage the service supply chain. To this end, understanding the core processes' effects on the overall service supply chain performance is of the essence (de Waart and Kemper, 2004). Indeed, without understanding the processes, it is practically impossible to understand the risks involved. However, considering that the most of the studies focus is on the service-oriented manufacturing supply chain, where the nature of services is typically not fully taken into account. Thus, in order to better distinguish the key features regarding the sources and nature of risks in service supply chains we must build a framework (Table 1). To this end, we utilize the discussion in the earlier section about the IHIP attributes of services.

In order to gain a holistic view of the service supply chain, the analysis of the risk features is conducted from three perspectives: service process, service offering and the service system. These correspond to the often used levels of analysis in supply chain management in general, regarding activities/individual risks, actors and the overall supply chain system (see Jüttner et al., 2003).

	<b><i>Intangibility</i></b>	<b><i>Heterogeneity</i></b>	<b><i>Inseparability</i></b>	<b><i>Perishability</i></b>
Service process (supply chain activity)	Activities utilizing knowledge and information	Heterogeneity in risks related to unique service activities	Service value co-creation processes taking place in the customer interface	The unique, non-repeatable and time-dependent nature of the process
Service offering (supply chain actor)	Intangibility and ambiguity of service offering	Heterogeneity of risks related to the unique service offerings	Customer-specific offerings and value co-creation	The non-standardizable nature of service offerings
Service system (supply chain/network)	Combined risks of the network due to intangible nature of interlinkages	Heterogeneity of risks related to the network actors, processes and their inter-linkages	Co-creation complexity in multi-actor service supply chains	The perishability of the value creation in service system level

Table 1. Key risk features in service supply chains

## **4 CONCLUSIONS**

Services are taking an increasing proportion of supply chain operations. The aim of service supply chain risk management is to holistically mitigate the risks to the supply chain. While the traditional supply chain management literature has been acknowledged not to be able to answer the challenges regarding service supply management, the current literature still lacks clear definitions of the special attributes that distinguish service supply chains from traditional manufacturing ones. In fact, there is very little research focused explicitly on this area, as the literature has mainly discussed supply chain risk management from the product- or provider-oriented perspective (e.g. de Waart and Kemper, 2004; Ellram, 2007; Arlbjørn et al., 2011). Thus, the aim of this paper was to instigate a conceptual discussion for the development SSCR. We argue that as services are different from products, the approach to risk management should differ for each, respectively.

We have proposed an analytical framework for key risk features in service supply chains. In doing this, we have combined the literature from various disciplines, including supply chain risk management (Jüttner et al., 2003; Ellram et al., 2004), logistics (Leuschner et al., 2013; Oflac et al., 2012), services management and marketing (e.g. Grönroos, 2000; Edvardsson et al., 2005; Jaakkola and Halinen, 2006; Ritala et al., 2013).

### **4.1 Theoretical implications**

The theoretical contribution of this study can be considered twofold. Firstly, service supply chain risk management should be understood in different levels (process, offering, system) in order to better take into account the risks that can hinder the successful delivery of the services. While the operations of service supply chain are more interlinked than those in the traditional supply chain, the risks can more easily affect more than one level of the service system. For example, some operational risks may be more damaging to the service supply chain because of the inability to store services.

Secondly, our recognition regarding IHIP attributes provides the initial idea of the distinctiveness of service supply chain risk management decision making. Previous studies in the field (e.g. de Waart and Kemper, 2004; Ellram, 2007) have highlighted the understanding service supply chains in order to gain better management over them. This study addresses this gap in the literature by illustrating the special features of services to the supply chain risk management.

### **4.2 Practical implications**

The results of this study enhance the practitioner's understanding about the nature of the service supply chain by describing the attributes of service supply chain. Furthermore, by use of the developed framework in decision making and risk analysis, practitioners are able to focus their efforts more accurately and thus are enabled to build better performance and resilience into the service supply chain.

### **4.3 Limitations and suggestions for future**

The most obvious limitation is in the conceptual nature of the study. There is a need for empirical studies, as well as for the further refinement of the framework from several viewpoints. For instance, one approach could be the utilization of identified risk features in building a larger theoretical and practical model for service supply chain risk management. In addition, the empirical studies could test the impact and level of the proposed risk features in different contexts with both qualitative and quantitative approaches.

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# **A CASE STUDY ON RISK-AVOIDED SUPPLY CONTINUITY MANAGEMENT THROUGH INFORMATION SHARING AND POSTPONEMENT**

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## **ABSTRACT**

This paper describes a real case about how ASE Kaohsiung (ASE\_KH) implemented both information sharing and postponement strategies to avoid supply discontinuity risk. ASE\_KH is one of the world's largest providers of semiconductor assembly and test services. They implemented the Integrated Business and Logistics Hub (IBLH) by providing an information hub (E-Hub) and a logistical hub (L-Hub) in their site and executed postponement strategy with its suppliers as part of their risk-averse supply continuity management plan. The effectiveness of the plan has been demonstrated by the supply discontinuity of ASE\_KH's major materials supplier in Japan due to the Fukushima earthquake and tsunami in 2011. To study the impacts of IBLH and postponement utilized by ASE\_KH on procurement risk management (PRM), we implemented on-site field study supplemented by secondary data about semiconductor industry and the case company. Besides delineating how ASE\_KH implemented the IBLH to achieve the goal of PRM, we also illustrate the collaboration between ASE\_KH and one of its major suppliers - Hitachi Chemical in Japan - in resolving the threat of supply discontinuity incurred by the Fukushima earthquake. This paper studies the case of ASE\_KH to demonstrate how information sharing and postponement strategy can be executed to successfully avoid supply discontinuity caused by devastating natural disasters. This research endeavors to acknowledge the issue of procurement risk management that has achieved much attention since the disaster happened in Japan but is still scarcely studied yet.

## **KEYWORDS**

Procurement risk management; information sharing; postponement; bullwhip effects; reverse bullwhip effects

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## **INTRODUCTION**

During 1999-2008, the world experienced two significant economic events - the Internet Bubble in 2000 and Global Financial Crisis in 2008 - which have induced volatile and shrinking demand. Such kind of demand incurred lumpy and excessive inventory for the supply chain of effected industries and this is the standard phenomenon of bullwhip effects (BE) resulted from downstream demand changes. The Fukushima earthquake and

tsunami in 2011 caused another effects on the world economy – the disruption of critical parts supply. The supply discontinuity affected industries globally by not being able to supply enough for those who need, which causes disruption of supply chains and can be regarded as reverse bullwhip effect (RBE). Many companies are forced to face seriously the sudden impacts of supply discontinuity on their supply chain. In Taiwan, one of the affected industries is the semiconductor industry, which had production volume of USD 54 billion for year 2012. In fact, the case company has experienced a lot of disruptions in the past ten years, which was mostly caused by external environment (see Figure 1). Those disruptions caused sudden accidents which provoked demand shutdown and supply shortage immediately and resulted in both forward / reverse bullwhip effects that hit the supply chain of semiconductor industry globally.

### **Bullwhip effects and reverse bullwhip effects**

Bullwhip effects have been noticed and studied by a number of studies (e.g., Geary et al, 2006, and Lee et al., 1997). Since the second half of 2008, the semiconductor industry has faced a serious economic downturn, which induced market volatility and inventory amplification in the supply chain. The BE were mainly arisen from the un-equilibrium of the supply and demand due to the drastic demand decline globally for semiconductor products. Since semiconductors are the basis for the electronics and IT industries, the effects are even more severe for semiconductor industry for its location at the far end of the supply side (Lee, 2010). Lee (2010) mentioned that the bullwhip effects can be tamed by collaboration among supply chain members with well-designed information systems across the supply chain.

Reverse bullwhip effects are caused by supply volatility. Besides the incidents that cause discontinuity of supply, when there is a greater variation in demand than in supply, reverse bullwhip effect persists in supply chains (Rong et al, 2008). Even though the latter has weaker effects than the former, it occurs quite often in the industry. For products that are not easily to be substituted or take much time to find an alternative source, as demand volatility increases to a level that suppliers cannot handle, they would ration out their supply to downstream customers. As the rationing occurs from the upstream, it amplifies and propagates to the downstream and creates larger and larger insufficiency of supply, which is referred to as RBE.

# ASE's Experiences in past ten years

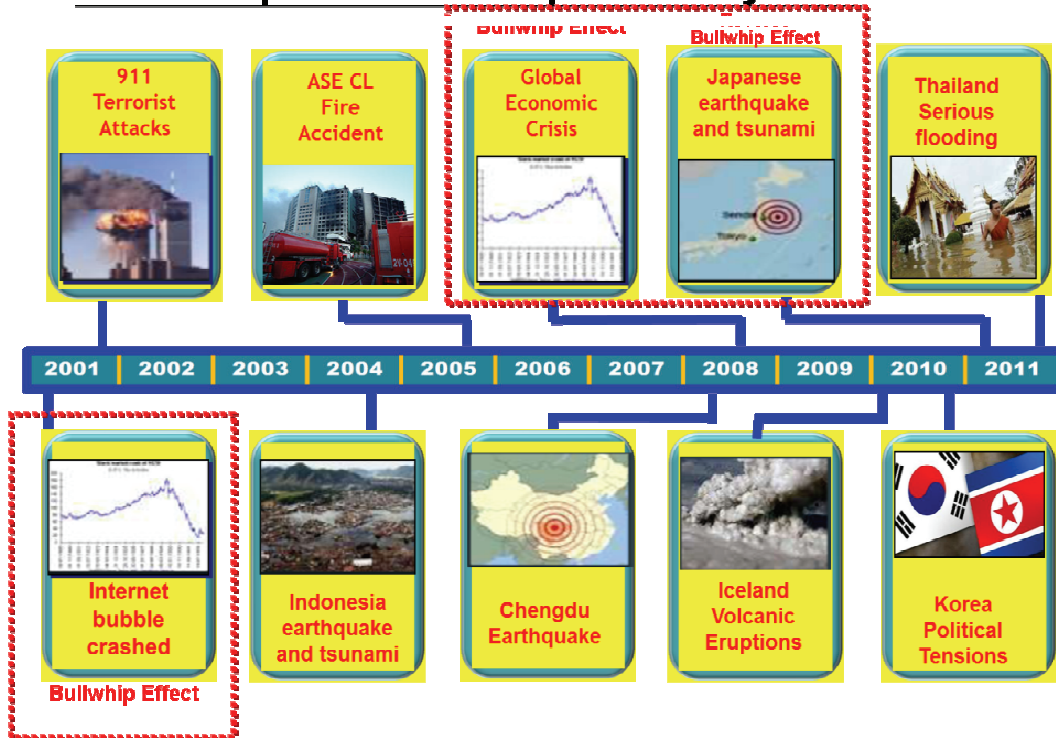


Figure 1: Supply chain disruptions in past ten years for ASE\_KH

The case company, ASE Kaohsiung (ASE\_KH), was founded in 1984 and is a member of the ASE Group, the world's largest service provider of semiconductor assembly and testing with sale revenue of US\$ 6.5 billion in 2012. Since ASE\_KH is at the upstream of the supply chain, the BE on ASE\_KH and its suppliers is more significant than on electronics manufacturers at the downstream. In 2008, ASE\_KH endeavored to mitigate the BE and has completed a 3-year project, which is to develop and deploy a web-based inter-business information platform – E-Hub to facilitate information sharing with its suppliers and integrated with the logistics hub (L-Hub) outsourced to a 3PL to consolidate material control and handling. Hitachi Chemical of Japan and several other major suppliers of ASE\_KH were among the first companies to participate in the project and provided inventory and shipping information to ASE\_KH. The successful experience encouraged other suppliers to use E-Hub and L-Hub. Since when the system was officially online in 2010, more than 300 suppliers (or 75%) have participated in the project and performed their daily works with ASE\_KH via E-Hub and stocked their parts at the L-Hub.

## FIELD STUDY AND INTERVIEWS

To study the impacts of IBLH and postponement utilized by ASE\_KH on procurement risk management, we implemented on-site field study supplemented by secondary data about semiconductor industry and the case company. By participating in the IBLH project of ASE\_KH, the authors made several field trips to the case company and conducted a few in-depth interviews with the managers and personnel involved in the program so as to understand how ASE\_KH utilized IBLH and postponement strategy to reduce procurement risks and the resultant supply risks to customers. Additionally, secondary data were also employed to get a better understanding of the semiconductor industry

and the influences of the 2011 earthquake on global supply discontinuity. In the following, we describe how the case company mitigate bullwhip effects and reverse bullwhip effects via information sharing and postponement strategies implemented at suppliers' sides.

### THE VALUE OF INFORMATION SHARING

Sharing information via the E-Hub has facilitated ASE\_KH and its suppliers to employ more effective inventory management models, such as JIT and VMI. In the VMI model, the 3PL service provider operates the L-Hub, and the inventory stored at the L-Hub is managed by suppliers. The L-Hub serves as an inventory buffer of materials for the suppliers. In this model, the suppliers are also responsible for inventory replenishment at the L-Hub. If the suppliers observe that inventory levels are below pre-determined thresholds, they will replenish inventories to base-stock levels. With the inventory information provided by the E-Hub, the suppliers can review periodically inventory levels and make production decisions accordingly. On the other hand, after receiving the shipping instructions from the suppliers, the 3PL service provider ships the order directly to ASE\_KH's production sites, as shown in Figure 2.

With the centralized (demand, inventory, order, and delivery) information shared via the E-Hub between ASE\_KH and its suppliers as well as the integration of information and material flows via the L-Hub, the BE in ASE\_KH's supply chain has been significantly mitigated. Particularly, because of the demand information shared via the E-Hub, during the development phase, ASE\_KH and its suppliers were able to quickly notice the economic downturn at the end of 2008 (i.e., the sales of electronic products dropped sharply by 70% due to the global financial crisis), and took necessary actions to resolve the impacts so as to avoid a huge disposition of inventory. Sharing information with suppliers is one of the main motivations for ASE\_KH to develop and deploy the IBLH. In 2009, one year after the initial deployment, ASE\_KH was able to reduce material preparation monthly from \$70 million to \$40 million and still increased the urgent demand fulfillment rate from 75% to 96%.

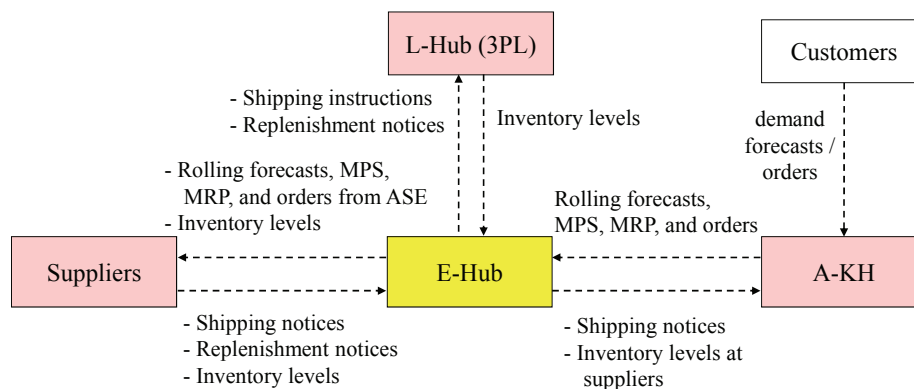


Figure 2: Information flows in the IBLH

### POSTPONEMENT AT SUPPLIERS

To further enhance supply chain performance, besides E-Hub for information sharing and L-Hub for material management integration, ASE moved one step further by implementing three types of postponement strategies with their suppliers, which are: (1) Purchasing postponement; (2) Logistics postponement; (3) Manufacturing

postponement. Even though ASE is a large company, some of the key components are supplied by few or the sole source because of economic and/or technological issues. Those components were supplied mainly on an MTO basis and thereby induced long lead time. After E-Hub was implemented, ASE could share demand information with their suppliers. Thus, instead of placing individual purchase orders (PO), ASE provide three-month blanket PO to suppliers who ship the component to ASE on the actual requirement, which is the purchasing postponement implemented at suppliers. For ASE's suppliers, the purchasing postponement has changed their MTO strategy to MTS based on three-month forecast orders from ASE, and this significantly reduces both their supply lead time and stocking levels by knowing forecast demand in advance. To implement JIT delivery, ASE further requested their suppliers to implement logistics postponement by stocking their supply components at the 3PL's or the L-Hub so that ASE could retrieve them on a daily basis. With logistics postponement at suppliers, ASE could have a better control over parts supply and better payment terms. In return, ASE provides low or free stocking fee for suppliers to stock their parts at the L-Hub.

Compared to purchasing and logistics postponement, manufacturing postponement involves more complex concerns because determining the appropriate postponement point requires a lot of engineering testing and economic evaluation. Among ASE's suppliers, Hitachi Chemical in Japan is a quite unusual one. They mainly supply ASE the compound, which is made from mixing epoxy, hardeners, fillers and additives, through several kneading and milling processes, to become compound powders. Powders are then mixed and casted to become ingots as final products. After ASE requested Hitachi Chemical to participate in their E-Hub system, Hitachi Chemical sent an engineering team to discuss seriously with ASE regarding why, how and what to cooperate with. It took Hitachi Chemical 6 months to figure out where to set the postponement point, and it turned out to be the point after powdering. From Hitachi Chemical's perspectives, combining manufacturing postponement with what had already been asked - purchasing postponement, they could reduce significantly the supply lead time as well as improving their production efficiency by implementing mixed MTS/MTO/postponement strategy to make the best use of capacity. The logistics postponement requested by ASE further lowered down their administrative work in Taiwan by outsourcing their 3PL work to the L-Hub, which creates benefits for both sides.

## **THE BENEFITS**

With E-Hub to share demand information and purchasing postponement, Hitachi Chemical reduces supply lead time from 8.6 to 3.6 weeks. The blanket PO combined with manufacturing postponement have made it possible for Hitachi Chemical to change their MTO strategy to mixed MTS/MTO/postponement strategy, i.e., MTS for processes up to the postponement point and MTO from blanket PO for processes after that point. Thus, even lead time was reduced by about 60%, Hitachi Chemical does not need to implement MTS and stock a variety of products but wait for confirmed PO from ASE for the last ingot casting and packaging processes. Finally, the logistics postponement and L-Hub have further realized JIT delivery and lowered down shortage supply ratio by more than 90%.

## **THE ORDEAL TEST FROM THE FUKUSHIMA DISASTER**

The Fukushima earthquake shook Japan and her industry in March 2011. For the semiconductor industry in Taiwan, JIT delivery strategy has created a high possibility of material supply breakdown from Japan. Fortunately, blanket PO as well as manufacturing postponement had made some of ASE's suppliers in Japan to switch from MTO to mixed MTS/MTO postponement strategy. Thus, suppliers stock about one month of semi-finished products at the postponement point. Since the processes after the postponement point usually are less complex, many of them can get back to production for processes after that point in about a week. In addition to the possibility of supply from manufacturers, there are components somewhere in the supply pipeline such as in-transit inventory, on-hand inventory and at-L-Hub inventory all together helped ASE to pass through the first month of supply breakdown for components from Japan. For example, Hitachi Chemical was still capable of supply their compound to ASE two weeks after the earthquake due to semi-finished materials stocked at the postponement point. On the contrary, ASE received augmented order amount from customers for fear of supply discontinuity, and so is the case for ASE's suppliers, which is the phenomenon of RBE. To mitigate the effects, ASE showed their customers the capability of continuous supply to reduce customers' order amount back to normal. Actually, two weeks after the earthquake, of the 26 critical components, only one was still at risk of discontinuity in a week (which was solved later on). The ordeal test of Fukushima earthquake demonstrated the successful implementation of E-Hub and the following three types of postponement executed by ASE's suppliers.

## **CONCLUSIONS**

Nevertheless the Fukushima earthquake and tsunami have reshaped supply chain deployment of many companies by applying the strategy of multiple supply sources, there are still few cases that have ever been reported. This paper addresses the issue by studying a real case of ASE\_KH to demonstrate how information sharing and postponement strategy can be executed to successfully avoid supply discontinuity caused by devastating natural disasters, which usually cannot be accurately predicted and prevented in advance. This research endeavors to acknowledge the issue of procurement risk management that has achieved much attention since the disaster happened in Japan but is still scarcely studied yet. The case study shed some light on how supply chain collaboration through information sharing and postponement can help companies in the supply chain to reduce supply and inventory risks and to mitigate both BE and RBE.

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## MITIGATING PRODUCT SAFETY AND SECURITY RISKS

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### ABSTRACT

A wide range of product recalls in recent years has raised the concern for mitigating risks associated with product safety and security. Latest academic research has focussed on mitigating product safety and security risks for product recalls within supply chains context (e.g. Speier *et al.*, 2011; Marucheck *et al.*, 2011). However, very little attention has been given towards predicting the underlying causes of product recalls (Bates *et al.*, 2007). The research discussed in this paper attempts to bridge this gap by a comprehensive study of multiple interdependencies and interrelationships associated with product recalls. Fuzzy rule base system in Failure Mode Effect Analysis (FMEA) is becoming the most popular method for risk evaluation (Liu *et al.*, 2013). Fuzzy approach is implemented in this research to identify the failures and to mitigate supply chain risks through a structured prioritisation.

### LITERATURE REVIEW

#### Product safety and security risk

A series of recent recalls in food (horse meat), medicine (energy supplements) and vehicle (Boeing battery) sectors have dampened public confidence in safety and security provided by manufacturers and the governments. Assuring the safety of products and services used by consumers is the focus of today's businesses. It has been observed through several other cases that the single product safety and security failure can have wider consequence on the global supply chain network. Hence, managing safety and security risks has become one of the priorities of current researchers and practitioners in broad domain of Supply Chain Risk Management (SCRM).

Safety and security risks not only pose a threat to the public, but also impact on the company's reputation and brand value. In case of vehicle recalls these risks have cascaded in terms of lost sales, reduced manufacturing output, increased marketing cost and reduction in new variants. Product recalls can also lead to an erosion of brand equity, loss of consumer confidence, and may have legal consequences (such as lawsuit and bankruptcy) (Bates *et al.*, 2005; Heerde *et al.*, 2007). Frequent product safety and security risks are observed in automotive industry sector as evidenced through media reports on vehicle recalls. "*Product safety can be defined as the reduction in the probability that use of a product will result in illness, injury, death or negative consequences to people, property or equipment*" (Marucheck *et al.*, 2011). According to Cai (1995), security is primarily concerned with systems capability to resist external attack and safety is related to special kind of failure causing disastrous consequences. "*Product security refers to the delivery of a product that is uncompromised by intentional contamination, damage, or diversion within the supply chain*" (Marucheck *et al.*, 2011). Although product safety and security are defined and treated as independent, we believe that safety and security risks are interrelated and strongly influence each other. Continuous improvement process is necessary to mitigate recall risks (Pyke and tang,



2010). Kumar and Schmitz (2011) attempt to mitigate supply chain risks by following a root cause analysis.

### **Fuzzy FMEA**

Vagueness, ambiguousness or imprecision are commonly referred to as 'fuzziness'. Fuzzy logic primarily focusses on quantifying the approximations in human thoughts and perceptions (Chiu and Chan, 1994; Kahraman *et al.*, 2000). FMEA has been widely used technique to identify and eliminate potential failures to improve the safety and reliability of the system. FMEA predicts Risk Priority Number (RPN) to measure the level of failure modes for a product or system. This information can be further used to mitigate the risks by making appropriate decisions. RPN is determined by three variables of the product namely severity, probability and detectability. In spite of its universal application, FMEA has multiple limitations such as, difficulty to predict probability of an event (Xu *et al.*, 2002), questionable criterion and formulation of RPN's, equally weighted RPN values creating evaluation complexity (e. g. Song *et al.*, 2013), several interdependencies being neglected (Wang *et al.*, 2009) and impracticality in assessing multiple failure modes with all possible combinations (Xiao *et al.*, 2011). Liu *et al.* (2013) provides a comprehensive list of all shortcomings through literature review on FMEA for risk evaluation. With so many limitations, the FMEA technique needs refinement and improvement (Gilchrist, 1993). Many researchers propose to combine AHP, ANP, TOPSIS and similar other methods to overcome some of the FMEA's limitations. Rational and accurate results still cannot be guaranteed following these methods. Hence, fuzzy logic-based approach to FMEA is being increasingly practiced. This model shift is clearly evident in recent academic publications published in various production, supply chain, reliability and risk management journals. In Fuzzy FMEA approach, several linguistic terms are expressed in trapezoidal or triangular fuzzy numbers to assess the ratings and weights for the risk variables (Wang *et al.*, 2009). Linguistic terms such as likely, important, very high are converted into tangible numbers. Each linguistic term can be modelled by a corresponding trapezoidal or triangular membership function (Wulan and Petrovic, 2012). Fuzzy logic based FMEA incorporates expert's knowledge and expertise to weight subjective and objective values of risk variables for clear evaluation.

Speier *et al.* (2011) uses a multi method approach to identify factors influencing supply chain risks leading to product recalls. Bates *et al.* (2007) follows regression analysis to predict increased safety and security risk due to vehicle recalls. According to Marucheck *et al.* (2011), how supply chains can learn to face product safety and recall issues is still an open research question. Tse and Tan (2012) handle quality and safety issue in product recalls by proposing marginal incremental approach. These are some of the recent research studies into identifying and mitigating safety and security risks within SCRM. Dani (2009) clearly identifies FMEA as an important tool for supply chain risk prediction. Limited recent literature clearly presents a gap and need for further research in this area.

### **RESEARCH APPROACH**

The research approach is based on the application of fuzzy FMEA technique to identify and prioritise the risks. The paper builds a conceptual understanding of safety and security risk through a vehicle recall dataset. The analysis is conducted using secondary data collected on vehicle recalls in the UK over the past decade (year 2000-2010) covering recalls from multiple global automotive manufactures. Vehicle recall data is obtained from Vehicle and Operator Services Agency (VOSA), an organization dealing with information related to automotive industry in the UK. This publically available dataset contains information regarding the manufacturer, make and model, production date, launch date and reason for recall.

Figure 1 shows total number of recalls from year 2000 to year 2010. On an average 200 recalls took place each year during this period. This is a significant number and increasing trend in vehicle recalls clearly demands in-depth investigation into underlying causes of rising safety and security risk. A 10 year dataset was selected in order to holistically capture any significant changes and patterns in the fault identification and their propagation.

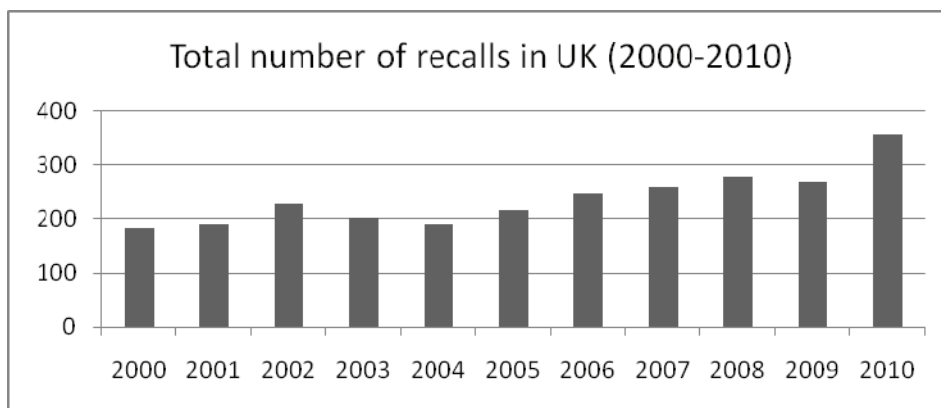


Figure 1: Number of vehicle recalls in UK (2000 to 2010)

Secondary data obtained from VOSA was cleaned and processed to the required format for the Fuzzy FMEA analysis. In fuzzy logic based FMEA approach, the three variables namely severity, probability and detectability are identified for each case based on a predefined scale. There are several scales proposed by different researchers in the past. We selected the one implemented by majority of the academics and practitioners. Liu *et al.* (2013) through his extensive literature review on FMEA suggests a 10 point rating scale for severity, probability and detectability variables. Fuzzification, fuzzy interface and defuzzification are the three systematic processes followed in any standard fuzzy expert system (Sivanandam, 2007). In the fuzzy interface module the risk variables are applied with membership functions to predict the degree of relationship. The crisp input is converted to fuzzy input in fuzzy interface. During defuzzification, these values are extracted into confidence values. Failure modes are ranked in order of its fuzzy RPN as an output. Figure 2 shows adapted fuzzy logic approach to identify the root cause of failures in vehicle recalls.

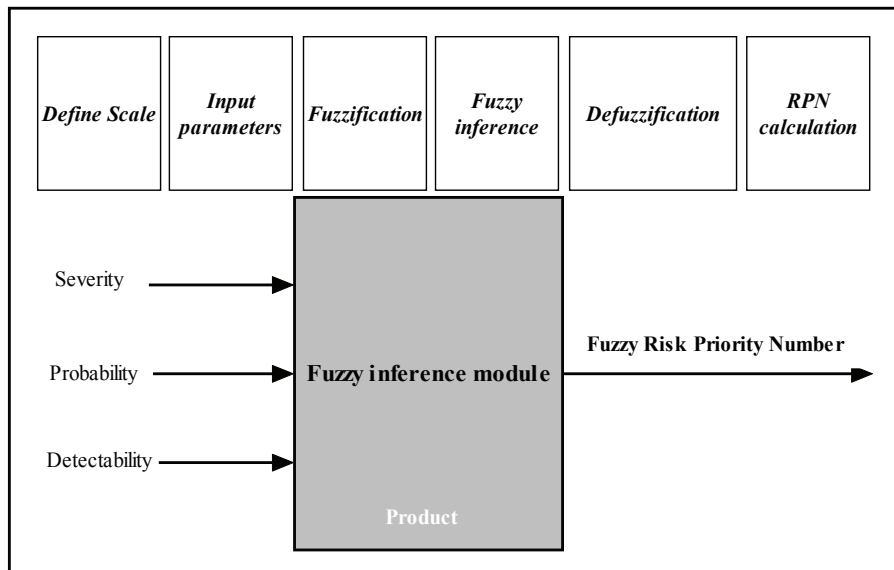


Figure 2: Fuzzy logic approach (Tay and Lim, 2006; Xu *et al.*, 2002)

## DATA ANALYSIS

Secondary data on vehicle recalls was filtered by converting technical specifications into required data format. Dataset recorded faults/concerns from multiple components from automotive vehicle. It was observed from dataset that most of the faults were either associated with engine, electronics or mechanism related issues. Past studies have utilised FMEA approach to identify faults from product design perspective, but we intend to study them from supply chain network perspective. In order to systematically study the root causes, we classified all the recalls into four major sub-systems: Engine, Electronics, Frame and Wheels (F&W) and Mechanism. Sub systemic classification also represents four different supply chain network required for supplier identification, procurement and quality management. Preliminary cause and effect analysis was conducted on each of these faults to predict their causes as seen in Figure 3. Root cause analysis, a systems thinking tool captures holistic and infrequent behaviour of risk (White, 1995). Ishikawa or fish bone diagram identified few important insights into root causes of vehicle failures.

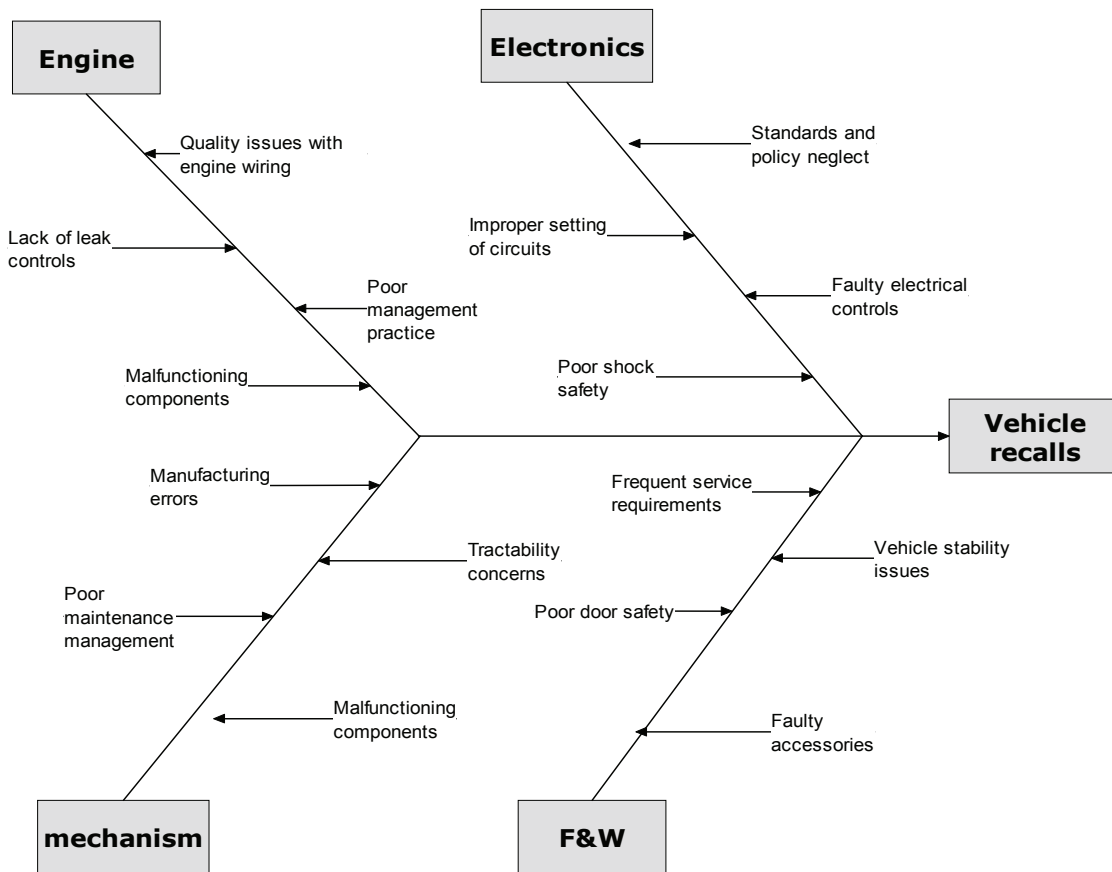


Figure 3: Root cause analysis for vehicle recalls

Based on preliminary root cause analysis it can be observed that, significant amount of faults originated due to poor use of material, inappropriate use of method or machinery, errors generated by people and management and inefficient inspection procedures. This shows that the failure modes can cascade from design to process, management and service stages. The relationship between four network modes, sub-systems and individual component represents the complexity in predicting the exact root cause for the failure. For example, Failure Mode (FM) 7 associated with a component in Frame (subsystem) might have caused due to excessive vibrations of a component in Engine subsystem. The fundamental issue of this vibration might be associated with a design activity within a system. Figure 4 shows the systemic representation of interrelationship between different failure modes. As seen, FM7 may also cause FM6 if not rectified. The connecting arrows (Figure 4) present causal effects and interdependent complex relationships.

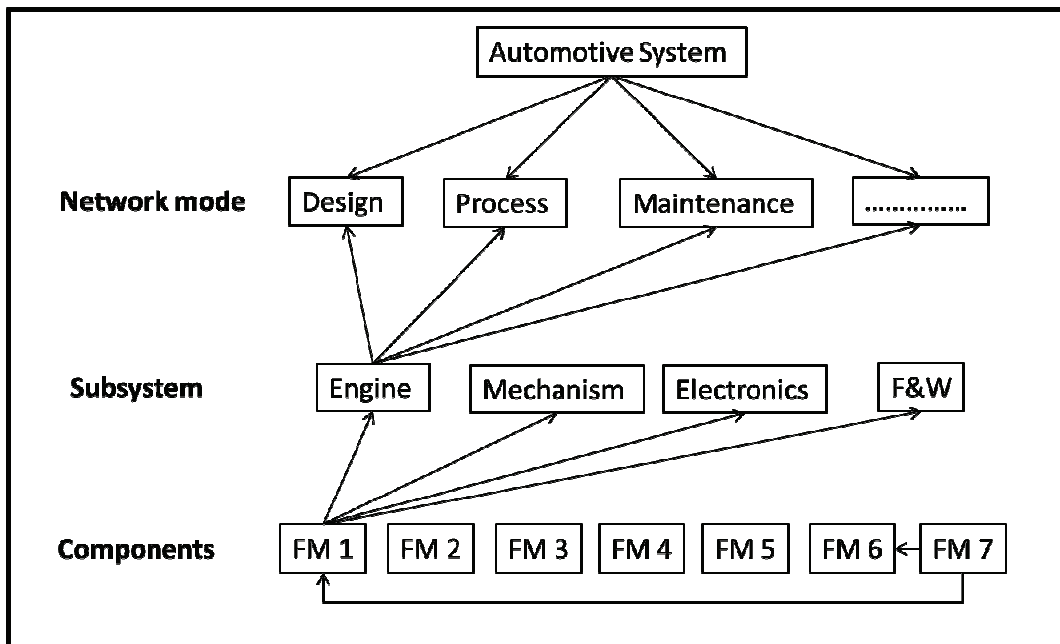


Figure 4: Interrelation of failure modes with system

10 point rating scale for severity, probability and detectability variables was adapted during the analysis (provided in the Appendix). As seen in the tables, the ranking of the variables use numbers to represent linguistic meaning. Following pre-defined scale, all the dataset were classified into linguistic risk values. The risks associated with safety and security are collated from the dataset for identifying overall importance for the failure mode. Risk Priority Number (RPN) values will be predicted in order to compare the results obtained for corresponding recall with Fuzzy RPN value. This comparison is expected to provide confidence in the results obtained and can further support in bringing some interesting methodological inferences.

## FUTURE RESEARCH AND CONCLUSION

The paper attempts to predict the fundamental cause for safety and security risk by capturing root causes of vehicle failure. The research intends to utilise fuzzy approach to predict supply chain risks associated with safety and security. Adapted fuzzy FMEA approach converts subjective/qualitative information related to vehicle recalls into Fuzzy RPN Numbers in order to implement the appropriate risk mitigation strategy. Input requirements for Fuzzy Interface module (Figure 2) are completed and the next stage is to study fuzzy interface module following fuzzification, fuzzy interface and defuzzification process. Fuzzy logic based FMEA will utilise the interdependent decisions to predict fuzzy RPN output, difficult to capture through other conventional approaches. Research study also expects to demonstrate the need for proactive identification of safety and security risk for effective risk mitigation in product recalls.

On-going research is still in infancy stage but believes to identify appropriate research gaps into the use of fuzzy logic to solve SCRM problems. Current research has been developed using case examples derived from literature, white papers and other secondary data sources. The causal linkages between different variables influencing the risk are highlighted with regards to the different failure modes within system. Input stage is completed and next stage of the research is to analyse and validate the results in order to create a conceptual framework for mitigating security and safety risks associated with product recalls. Fuzzy approach to SCRM will provide a new perspective for managers to prioritise and mitigate risks within supply chain network. The outcomes

of this research are expected to support researchers and practitioners in building resilient strategies for proactive risk identification and mitigation.

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## APPENDIX

### Rating for severity, Probability occurrence and detection (Liu et al., 2013)

Table I: Scale for Probability of failure ranking

Probability of failure	Possible failure rates	Rank
Extremely high: failure almost inevitable	1 in 2	10
Very high	1 in 3	9
Repeated failures	1 in 8	8
High	1 in 20	7
Moderately high	1 in 80	6
Moderate	1 in 400	5
Relatively low	1 in 2000	4
Low	1 in 15,000	3
Remote	1 in 150, 000	2
Nearly impossible	1 in 1,500,000	1

Table II: Scale for Severity of failure mode ranking

Effect	Criteria: severity of effect	Rank
Hazardous	Failure is hazardous and occurs without warning. It suspends operation of the system and/or involves noncompliance with government regulations	10
Serious	Failure involves hazardous outcomes and/or noncompliance with government regulations or standards	9
Extreme	Product is inoperable with loss of primary function. The system is inoperable	8
Major	Product performance is severely affected but functions. The system may not operate	7

Significant	Product performance is degraded. Comfort or convince functions may not operate	6
Moderate	Moderate effect on product performance. The product requires repair	5
Low	Small effect on product performance. The product does not require repair	4
Minor	Minor effect on product or system performance	3
Very minor	Very minor effect on product or system performance	2
None	No effect	1

Table III: Scale for Detection of failure mode ranking

<b>Detection</b>	<b>Criteria: likelihood of detection by design control</b>	<b>Rank</b>
Absolute uncertainty	Design control does not detect a potential cause of failure or subsequent failure mode; or there is no design control	10
Very remote	Very remote chance the design control will detect a potential cause of failure or subsequent failure mode	9
Remote	Remote chance the design control will detect a potential cause of failure or subsequent failure mode	8
Very low	Very low chance the design control will detect a potential cause of failure or subsequent failure mode	7
Low	Low chance the design control will detect a potential cause of failure or subsequent failure mode	6
Moderate	Moderate chance the design control will detect a potential cause of failure or subsequent failure mode	5
Moderately high	Moderately high chance the design control will detect a potential cause of failure or subsequent failure mode	4
High	High chance the design control will detect a potential cause of failure or subsequent failure mode	3
Very high	Very high chance the design control will detect a potential cause of failure or subsequent failure mode	2
Almost certain	Design control will almost certainly detect a potential cause of failure or subsequent failure mode	1



## **AN APPLICATION OF SUPPLY CHAIN RISK MANAGEMENT IN A FERMENTED VEGETABLE CANNED FACTORY IN THAILAND**

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### **ABSTRACT**

**Purpose** – This paper seeks to explore how supply chain risk management has been implemented in a fermented vegetable canned factory in Thailand. Sources of risks have been identified and most of them arise from an absence of alignment of inbound supply chains.

**Design/methodology/approach** – Both qualitative and quantitative was conducted to explore the status of supply chain risk management of the case study. Supply chain risk matrix was delivered by Delphi method. A survey was conducted to investigate the problems of inbound supply chain. Quantitative analysis such as regression modelling was run to find out the significant factors that could affect on the supply chain stability.

**Findings** – Top three risks factors of the case study are found in the inbound supply chains that are material quantity, material quality and high material cost. Factors have influenced on the material quality, quantity and costs are analyzed.

**Research limitations/implications** – This is a case study of a vegetable canned factory. While this is a case study paper, the existence of occurring supply chain problems is very likely to be found in other factories. Main reasons are the factories do not own farms and most of them do not have contract-farming. Supply chain planning is then complicated and needed to adjust frequently.

**Originality/value** – The case study's supply chain are mainly affected by raw material sufficiency in terms of quality and quantity. Raw material pricing is significantly depend on other vegetable demands and directly leads to planting plan changed by growers. Supplier relationship management together with Good Agricultural Practice (GAP) would need to adopt to obtain the inbound supply chain stability.

**Keywords:** Vegetable canned factory, Supply chain risk management, case study

### **INTRODUCTION**

The agricultural industry is one of the most important sectors in Thailand. Fresh vegetable and fruit produces and cans are being exporting and creating significant revenues to the country. The agricultural industry has a great impact on labour and product contents as all of its products are adding on its value in the country. The growth of the products is increasing towards the world population. To obtain a sustainable growth, vegetable and fruit supply chains in Thailand would need to meet customer satisfaction in terms of quality, quantity and time.

Supply chain management concepts has been viewed as networks of organizations from the upstream to downstream that are synchronising and collaborating to improve activities, product and service values in order to meet customer satisfaction. For Thai vegetable canned products, their supply chains include growers, intermediate manufactures such as canning manufacturers and sugar manufacturers, fermented canned manufacturers, logistics service providers and also traders. It can be seen that many organizations are involving in Thai vegetable canned supply chains especially growers. About 90 percent of a fermented canned product is fresh vegetable. Growers then play an important role in the fermented vegetable canned supply chains. The growing method and weather may highly affect on the inbound supply chain stability. Moreover, most of Thai growers are not contract growers and the fermented vegetable canned factories do not own farms. The ability to control inbound supply chains would be problematic and directly affect on customer satisfaction.

In addition to these, the case study would need to consider on supply chain risk management to satisfy customers' requirements. The objectives of supply chain risk management are then to minimize or eliminate supply chain disruptions. Many researchers proposed sources of risks that could affect on supply chain risks. Christopher and Peck (2004) classified supply chain risks into 3 main groups that are 1) internal to the firm, 2) external to the firm, but internal to the supply chains, and 3) environmental. Demand and supply are subgroups of the external category. Chopra and Sodhi (2004) noted sources of supply chain risks and their drivers. Disruptions were classified as one of risk categories that are driven by natural disaster risks, supplier bankruptcy risk and depending on a single source risk. Systems, forecast, intellectual property, procurement, receivables, inventory and capacity were included in their risk categories. Mitigation approaches were proposed. It can be seen that supply chain risk factors have been proposed differently. Wagner and Bode (2008) conducted an empirical study to investigate on supply chain risk sources and the relationship between supply chain risks and supply chain performance. Demand and supply were found as significant supply chain risk sources.

It is needed to consider supply chain risk sources for each supply chain as types of product, sizes of supply chain networks, information technology used and so on can directly affect on supply chain risks differently. The case study needs to produce finished products to match with customers' requirement in terms of quality, quantity and time. Then, it is essential to analyze supply chain risks of the case study in order to reduce or eliminate supply chain disruptions.

## **BACKGROUND OF CASE STUDY**

The case study is a fermented vegetable canned company limited located in Thailand. It has been established more than 40 years. It is producing many kinds of fermented vegetable cans such as seasoned pickled mustard green, fermented mixed vegetables with shitake mushroom, fermented mixed vegetable and so on. The case study has 2 factories located in the north of Thailand which is very near to planting farms. The factories are certified for ISO 9000, GMP and HACCP. Its markets are both local and

international. The international market is growing well comparing to the local market which is quite stable. To produce a fermented vegetable can, it is need a good supply chain plan as it takes about 55 days per one crop. Although some of vegetable growers are contract farming, they could sell their vegetable to other companies and switch to other vegetables if other vegetable prices are higher. In other words, there is not much different between non-contract farming and contract farming. Moreover, the case study does not own any farm. This could lead to uncertainty in supply chains.

When growers transport their fresh vegetables to the factory, the fresh vegetables have to be inspected according to the quality standard. Too big, too small and bruised vegetables will be rejected. An example of quality cabbages is defined as having 3 outer leaves, wrapped head, no rot and non-flowering. The quality vegetable will be cleaned and fermented with other ingredients. The finished products will be sent to warehouse of the case study located in Bangkok. The warehouse is done manually, but there is a plan to apply bar coding and warehouse management system.

## **METHODOLOGY**

### **Identification of Supply chain risk scores**

Delphi method was conducted to identify supply chain risks. A group of staff in sales, production, procurement and logistics was asked to identify sources of supply chain risks for the first questionnaire. The sources of risks are identified in 2 categories that are internal factors and external factors. The internal factors are internal issues of the case study and the external factors are both internal and external to the supply chain. The details of supply chain risks are shown in table 1. Index of Item Objective Congruence (IOC) was carried out and found that 49 issues of supply chain risks have more than 0.5 IOC.

<b>Internal factors</b>	<b>External factors</b>
Sales and marketing Production Warehouse Inventory Transport Information system Organisational management Human resource management	Environment Raw material Customer response Competitor Technology

Table 1: Sources of supply chain risks

The second round of questionnaire with having 49 issues of supply chain risks were distributed to 30 staff. We asked them to give scores on impact and possibility to rank supply chain risk scores. A supply chain risk matrix was carried out. Top ten supply chain risk scores are shown in table 2. Insufficient of incoming raw material is the

highest risk and follow by high raw material costs and non-conforming raw material, respectively.

No.	Risks	Score	Impact
1	Incoming raw material insufficiency	11.75	High
2	High raw material costs	11.32	High
3	Non-conforming raw material	10.86	High
4	Demand change	10.44	High
5	Customer behavior change	10.14	High
6	Substitute products	9.70	Medium
7	Economic impact such as exchange rate	8.42	Medium
8	Competitors	6.62	Medium
9	Too few new products offered	6.48	Medium
10	Unable to expand to new markets	6.35	Medium

Table 2: Supply chain risk scores

### Analysis of root causes

A focus group was conducted to determine root causes of top three supply risk scores. Four main factors directly affect insufficient of raw materials. Firstly, environment changing such as too heavy rain or too hot temperature will have an effect on vegetable yields. Secondly, a sourcing plan is inefficiency due to plantation planning errors, vegetable forecast errors and delay to purchase. Thirdly, contract growers do not keep their promise by changing to grow other vegetables and selling to other companies.

The **second supply risk score is high raw material prices. The main reason is** not having enough vegetable produced because growers turned to grow other kinds of economical vegetable as the raw material prices had been low or very low during the previous crop. The third high risk score is non-conforming raw material. Two main factors are growers and environment. If growers do not follow Good Agricultural Practices (GAP), the fresh produces could be damaged by having rots, flowering, etc. Too hot weather or too heavy rain will deteriorate vegetable's quality.

It can be seen that factors affect on the supply chain risks can be classified into 2 groups that are controllable and uncontrollable. Controllable factors that are raw material pricing that directly influence the vegetable quantity and quality affected by growers' practices.

## RESULTS

### Raw material quantity and quality analysis

To identify significant factors related to raw material quantity and quality was conducted by using a questionnaire survey. Thirty eight growers were interviewed to investigate

their planting behavior on cabbages. We selected cabbages to consider as it was a main raw material of the case study. Secondary data of other economical vegetable prices, their planning volumes, percentage of cabbage damaged and so on were gathered. Multiple regression analysis was run to investigate on quantity and quality raw material. Cabbage pricing was analyzed by the use of a polynomial regression model to find significant external factors.

Firstly, we would like to discover factors that would affect on quantity and quality uncertainty. Growing method factors and post harvesting method factors were analyzed to find their relationship with conformance cabbage quantity. Eight teen factors were put into the regression model. Finally, 5 factors were significantly related with the cabbage quantity.

$$Y = -816.743 + 0.497X_1 + 350.499X_{11} - 283.903X_{15} - 193.057X_{10} + 47.967X_{17}$$

While Y is the percentage of quality cabbage per the number of cabbage planned and  $X_1$  is the planning area. The other factors are relevant to growing and post harvesting methods.  $X_{11}$  is the percentage of 3 outer leaf cabbages.  $X_{15}$  is the percentage of rot cabbages. The percentage of flowering cabbages is  $X_{10}$  and  $X_{17}$  is the wrapped head cabbage percentage. It can be seen that planning area has less affected on the cabbage yields comparing to other post harvesting methods. The 3 outer leaf cabbages have the highest positive impact on the yields. We can conclude that the yields will mainly be influenced by post harvesting and growing methods. However, there are other factors that are negatively affecting on the yields and they were unexplainable.

Then, we tried to investigate the factors that may play an important role in the interception of the previous regression model. We conducted a deep interview with the procurement manager and production manager and they also had some questions on pricing issues that could lead growers moving to other economical vegetables. We analyzed cabbage selling prices with other factors that are production cost of cabbage, corn selling prices, rice selling prices and so on. A polynomial regression model was found to be significant as following these.

$$P = 2.682PD + 2.578E-7(PE*PH) - 2.280E-5(PC*PF)$$

P is cabbage selling prices. PD is production cost of cabbages. PE is the cabbage yield planned by the case study. Corn growing quantities is PH. PC is rice selling prices and PF is fresh cabbage quantities received at the factory. It can be deducted that corn quantities together with the cabbage yield planned have a positively impact on cabbage selling prices. If the corn quantities are high, the cabbage selling prices will be high as well. Corn could be a substitute vegetable for growers choosing to grow. While rice

selling prices and the cabbage received quantities have a negatively impact on the cabbage selling prices.

## **DISCUSSION AND CONCLUSION**

The highest risk scores are uncertainties of cabbage quantity and quality. Although we did construct a regression model to investigate significant factors that could affect supply chain performance, there was a very high constant found in the model. Factors not included in the model such as soil, temperature and rain will directly affect on quality and quantity of cabbages. Good practices in growing and post harvesting directly affected on quantity and quality of cabbages. Setting up hose spray watering or sprinkler watering can improve both quality and quantity, but hose spray watering give better yields than sprinkler watering. Using both chemical and organic fertilizers significantly give more yields comparing to using chemical fertilizers alone. Good Agricultural Practices (GAP) should be transferred to the growers. Post harvesting methods need to be followed such as no watering 10 days before cutting, having 3 outer leaves after cutting and leaving cabbages cut for 2-3 hours before packing. To achieve the sourcing plan, the case study should employ more staff to give suggestions on GAP to the growers and also to monitor the growers on farms.

Corn is a competing vegetable. The growers can turn to grow corns instead of cabbages. The corn growing lead time is almost the same as that of cabbages. The previous season of cabbage pricing can then drive the supply of corn. Although some growers are contract-farming, they could change to grow other vegetables. The main reason is that the case study will not do any law enforcement on contract growers as it is very costly comparing to the cabbage costs. However, the most import factor is cabbage production costs. Pricing model of the case study may need to reconsider together with supplier relationship management.

Mitigation approach proposed would be 1) forecast improvement, 2) supply chain planning setting up, 3) supplier relationship management, and 4) cabbage research and development.

Firstly, a forecast improvement project should start to get more factors into the supply model. Planting quantities and prices of other vegetables may affect on cabbage planting quantities. The planting quantities of each year could be collected from the agricultural and cooperatives ministry of Thailand. Moreover, a cabbage pricing model should be reinvented with covering those factors affecting cabbage planting quantities. Secondly, supply chain planning would need to set up to synchronize inbound planning with production planning and outbound planning. The supply chain planning can be updated according to supply situation. Thirdly, supplier relationship management program must start from selecting qualified suppliers. Approved Vendor List (AVL) will be listed and the growers on the list must be contract farming. Total sourcing lead time will be needed to reduce to allow the growers could get the money early. Then,

continuous intensive training on GAP must be given to the growers. Finally, cabbage research and development needs to improve cabbage to be able to stay in hot weather.

The case study is having some difficulties on inbound supply chains especially on cabbage growing. In 2015, ASEAN will become one. It may be a good chance for the case study to expand its contract farming to Lao PDR as there will be a new bridge connecting the northern part of Thailand with Lao PDR. Moreover, new demand may rapidly grow in the near future as well.

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# **EXPLORING DECISION-MAKING FACTORS OF RISK DISTRIBUTION STRATEGY IN SUPPLY CHAIN: A CASE STUDY OF THAI AUTOMOTIVE INDUSTRY**

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## **INTRODUCTION**

Supply chain in today business world is so complicated due to the fact that every organisation competes each other by sourcing with good quality and cheaper material price. Complexity of supply chain easily leads to uncertainty performance and that impacts to risk occurrence in supply chain. In the past decades, research in risk and risk management have been widely attention. Several studies have discussed about risk management knowledge and risk management application in supply chain (Juttner et al. 2003; Juttner 2005; Norrman & Jansson, 2008; Manuj & Mentzer, 2008). Risk management strategies are in particularly studied for the application in supply chain, for example, risk allocation, risk postponement and risk hedging, were also raised up through the use in supply chain (Ng & Loosemore, 2007; Waters, 2007; Manuj & Mentzer, 2008).

However, risk distribution strategy which is applicable to many disciplines, has not gained sufficient attention in supply chain research. It found that only four articles about this subject have been published in peer-reviewed international journals (Anon., 1964; Roberts, 1978; Forte, 1987; Ji, et al, 2009). These papers had discussed only the liability of ownership.

Banomyong and Yingvilasprasert (2010) therefore originally developed the conceptual framework from the relevant literature and Banomyong and Yingvilasprasert (2012) established the definition of risk distribution strategy for the use in supply chain context. Further study of empirical evidence is so meaningful to academic researchers and to business practitioners for understanding which decision-making factors related to risk distribution strategy in supply chain. Hence, this research work is to extend the body of risk distribution knowledge by exploring decision-making factors. The remainder sections of this paper cover: literature review, research method, key findings, discussion with prior work, and conclusion and further study.

## **LITERATURE REVIEW**

In prior research, Waters (2007) developed the concept of supply chain risk management (SCRM) from two theories: (1) risk management and (2) supply chain management. SCRM has discussed with three steps: (1) risk identification, (2) risk assessment, and (3) risk mitigation. The first two steps are commonly applied in every organisation whereas the last step depends on organisation's judgement. There are



many strategies applied in risk mitigation steps such as risk allocation, risk avoidance, risk security, risk postponement, risk control, risk hedging, risk transfer, and risk sharing (Ng & Loosemore, 2007; Waters, 2007; Manuj & Mentzer, 2008). Each strategy has been discussed through the use in business practice and it is proven for effectively delivery risk mitigation. However, there is no evidence disucssed about risk distribution application in supply chain.

Risk distribution strategy was firstly published in law by Steyer et al. (1940). Later, the application is extended to many disiplines such as Medical science, Finance, and Legal field (Steyer et al., 1940; Calabresi, 1961; Pollack, 2001; Norozi et al., 2006; Vassallo, 2009). In these disciplines, risk distribution highlighted to the areas and parties which risk being distribututed to, likewise, how to prevent such distribution in the future (Pollack, 2001; Gao et al., 2001; Hay et al., 2004; Norozi et al., 2006).

For supply chain discipline, there was no discussion about its application. Thus, it can say that risk distribution is in infacy stage and still needs to be further investigated. This research work aims to fill research gap by exploring relevant decision-making factors.

### RESEARCH METHOD

A case study of automotive industry in Thailand is conducted to investigate decision-making factors which can deliver the success of the risk distribution strategy. Seven automotive companies are chosen from different organisation type and characteristics (Eisenhardt, 1989). Automotive industry was selected because it is the most rigour and roubust supply chain in Thailand. The methodology employed in this research includes the use of semi-structured interviews. All interviews with the average duration of 40-60 minutes were tape recorded and carefully transcribed. The key question was on what the factor(s) is related to distribute the risk out from the firm. Moreover, content analysis is used for data analysis and interpret the findings.

Table 1 hereunder describes Respondent's position and the case companies' demographics.

#	Respondent position	Firm characteristics	Position in supply chain	Management style	# of staff	# turnover / year
I	Business owner	Part maker	2nd tier supplier	Thai	13 staff	12 MTHB/year
II	Manager	Part producer	1st tier supplier	Japanese	50 staff	40 MTHB/year
III	Business owner	Part maker, Trading & Distributor	REM	Thai	15 staff	30 MTHB/year
IV	Assistant Manager, Procurement	Assembly manufacturer	Automaker	Japanese	8,000 staff	30,000 MTHB/year
V	Production supervisor	Part procedure & Part assembly	1st tier supplier	Thai / Japanese	150 staff	230 MTHB/year
VI	Business owner	Assembly manufacturer	OEM	Thai	1,300 staff	2,000 MTHB/year
VII	Manager	Assembly manufacturer	Automaker	American	3,500 staff	9,000 MTHB/year

Table 1: Respondent's position and the case companies' demographics

## KEY FINDINGS

From the different type of organisation, the common findings lead to classify decision-making factors into three groups: (1) risk distributor's rationale, (2) risk characteristics, and (3) characteristics of risk receivers. Each group has hereunder described.

### Risk distributor's rationale

In fact, implementing risk distribution may impact relationship between risk distributor and risk receivers. Most respondents then agreed to apply risk distribution when they have critical risk to be managed. Table 2 hereunder summarises all situations which organisation may encounter when deciding to distribute the risk out. As a result, the following three situations are demonstrated for when risk distribution strategy is begun.

Observed items	Freq.	Observed items	Freq.
1. No budget	7	2. No knowhow	5
3. No knowhow	5	4. No qualified staff	5
5. No sourcing ability	5	6. No machining capability	5
7. No technology capability	5	8. No execution capability	5
9. No support capability	6	10. Inadequate budget	7
11. Inadequate knowhow	5	12. Inadequate qualified staff	5
13. Inadequate sourcing ability	5	14. Inadequate machining capability	5
15. Inadequate technology capability	5	16. Inadequate execution capability	5
17. Inadequate support capability	6	18. Reject to manage risk	7

Table 2: Content analysis of risk distributor's rationale

#### 1. No risk management capability

Implementing SCRM strategy needs capability to support. If a firm does not have enough capability to mitigate risk, they have to invest more and spent time to be capable one (i.e. a firm has to provide training to staff or invest more machines). If risk needs to be urgently managed, the choice to increase support capability within time limitation is therefore not workable.

The first situation here is extremity because a firm has no capability to support their selected SCRM strategy. Since each strategy needs different capability to support, hereunder lists are therefore summarised.

1. *Budget* – this capability is required for the investment of machines, staff recruitment, and other resources in order to have enough capability to manage the risk. For example, a firm buys more machines to increase production capacity and that results in demand risk reduction.
2. *Knowhow* – this capability is required when implementing SCRM strategy. If a firm doesn't have enough knowhow, they may implement the strategy with improper way. And that, risk management cannot be success. For example, risk allocation strategy requires knowledge on how to allocation the risk. Some firms

prefer using allocation on activity base whereas another prefers using allocation on budget base. Both preferences are selected based on business environment and dominant issues.

3. *Qualified manpower* – this capability means skilled or expert staff to implement SCRM strategy. Although a firm provides in-house training to staff, but some strategies requires more experience. Experience can introduce the right way to deliver outcomes faster and enhance the effective of risk management programme.
4. *Sourcing ability* – this capability aims to mitigate supply risk. The situation refers to when suppliers cannot supply raw material to a firm on time, to serve highly fluctuated demand. So, a firm needs sourcing ability on how to find back-up suppliers and contingency plan, especially the supply of long-lead time and/or licensing materials.
5. *Machine capability* – this capability refers to the ability of single machine which can produce many parts. Normally, engineers create special features input to new car model. If the machine cannot be modified, a firm has to buy new one. However, it is impossible for firms to invest all kinds of machines.
6. *Technology capability* – this capability is applicable when selected SCRM strategy requires more technology. The use of technology helps to reduce risk from human error and defective production. In some case, fraud in organisation is additionally eliminated.
7. *Execution capability* – this capability is applicable when implementing SCRM strategy. Although a firm has good mitigation plan, but they cannot mitigate the risk well without good execution process. Most firms start to implement with clarifying benefits of risk management to staff and why they have to do. However, the starting process normally takes time and that is not appropriate to manage critical risk.
8. *Support capability* – this capability means the facilities support when implementing SCRM strategy. The facilities are exemplified by storage space, energy supply, fixing/repairing, and safety/security system. Transportation access is one of the support capabilities. This support was noted since the 2012 Great Flood Crisis in Thailand.

The aforementioned capabilities are listed according to findings. However, a firm may lack different capability if they apply the same strategy in different time. Thus, it depends on how a firm finds the most appropriate way to save budget and time for risk management in their organisation. Risk distribution is finally employed if they have no choice.

## **2. Inadequate risk management capability**

This situation refers to when a firm manages risk with their existing capabilities (as presented in aforementioned section) but not adequate to mitigate the whole risk exposure. In this case, they have to find additional way help for risk mitigation. Running two strategies at a time needs a firm put a lot of effort. Most respondents then decide to distribute the risk out.

There are two examples for clarifying this situation. The first example is to solve demand risk and the second example is to reduce operational risk.

Example 1: Company ABC gets unexpected order (demand risk) from their customer and this order has to be delivered in a month. A firm can only produce half of that order otherwise it will interrupt other customers. In this case, a firm distributes the rest of order to two suppliers. Two suppliers here are selected based on available production capacity. At the end, company ABC collects all the orders and deliver to customer on time.

Example 2: Company XXX gets an order to produce five special features from automaker. However, current machine at the company can only produce two features of product (operational risk). So, company B decides to distribute the rest of three features to another two companies (one can produce two features and another can produce one feature). At the end, company XXX can deliver outstanding throughput to automaker.

From the examples, it is observed that a firm will absorb risks as much as they can so that conflicts to receivers are minimised. Thus, it is not surprising that this situation is the most found from the respondents.

### 3. Reject to manage risks

Only this situation a firm does not focus on risk management capability. The firm does not decide to manage the risk because such risk is irrelevant to business competency. This reflects the fact that managing insignificant risk may lose business attention and limit business opportunity. A firm thus gives the risk to others who can better perform risk mitigation. To reduce risk return, a firm gives the risk to only receivers where a firm can control.

In conclusion, risk distribution is not specified to suit with any particular organisation type/characteristics. Each organisation has different rationale to apply risk distribution strategy. Commonly, risk distribution is applicable when needs immediate action. In the next section, risk characteristics will be discussed for particularly used with distribution strategy.

### Risk characteristics

Similar to other strategies, characteristics of risk is very important factor to sort out the most appropriate risk mitigation approach. Risk characteristic then becomes the second decision making factor encouraging firms to perform distribution activity. Table 3 illustrates the content analysis of all potential risk characteristics being distributed. As mentioned before, risk management in automotive supply chain is concerned at a firm level. Once risk can be controlled, it will not expose through supply chain.

Observed items	Freq.	Observed items	Freq.
1. Not return future loss	7	2. No impact to higher cost	6
3. Not increase competitors	5	4. No impact to critical parts	6
5. No impact to firm reputation	5	6. Not related to sensitive part	6
7. No impact to customer satisfaction	5		

Table 3: Content analysis of risk characteristics

Risk distribution strategy has been implemented after risk occurs at a firm. It can serve all types of risk, especially, operational and supply risk types. However, only particular characteristics go well with distribution process. A firm decides to distribute the risk which will not return future loss, i.e. risk which does not allow receivers increase competitive environment. As a result, risk receivers may become an alternative source for customers. A firm then prevents such future loss by distributing only some process/knowhow out. In addition, if firms ensure that risk receivers are incapable to invest resources for the whole production process, a firm is braver to distribute all of the risks out.

On the other hand, some characteristics of risk are not appropriate for risk distribution. The findings present the following characteristics of risk that may consequent to future loss.

1. Risks that increase budget and unit cost –every organisation in automotive supply chain has limited budget to produce their parts. If giving the risk to others and

highly impact to cost structure, risk distributor will find other solutions rather than distribute out.

2. Risks that impact to firms' reputation – surely for a firm that they do not want to lose customers. Distributing to other receivers, a firm has to definitely ensure the quality of product and on time delivery. Otherwise, it may impact to a firm's reliability and customer satisfaction at the end.
3. Risks that not impact to critical parts or sensitive parts – critical parts are not distributed because the delay of delivery may impact the following process. While, sensitive parts require skilled and experiences for operating more detailed job. Both parts are very difficult to control at the others and also highly impact to customer satisfaction.

Risk distribution is therefore appropriate to all types of risk but only for some characteristics.

### Characteristics of risk receivers

Risk receiver is surely important for distribution process. Selecting capable receiver is then necessary to reduce risks exposed in supply chain. Capable receiver means the one who can manage the risk well. A firm decides not to distribute the risk if no capable risk receivers are presented.

Due to the fact that each organisation can professionally manage some kind of risk, a firm then uses risk characteristics to search for capable receivers. Table 4 illustrates the content analysis of risk receivers' characteristics. The referred criteria are applied to justify whether to be capable risk receivers. Furthermore, these criteria are employed to identify amount of risk spreading to each chosen receiver.

Observed items	Freq.	Observed items	Freq.
1. Near location	5	2. Good historical record	5
3. High production capability	6	4. High financial capability	6
5. High manpower capability	5	6. Reputation to manage risk	6
7. Operate under budget	6	8. Good relationship with	6
9. Good communication to	5	10. Lower bargaining power	5

Table 4: Content analysis of risk receivers' characteristics

1. *Near location* – this factor is highlighted by most respondents. It is truth that near location allows a firm easily go there and closely monitor risk receivers. For production, near location also encourages on-time supply. Firms thus ensure less impact to the delivery to customers.
2. *Good historical record* – a firm will distribute the risk to receivers who have good performance in previous job. Good historical record allows a firm ensure the delivery of risk management by receivers. Relationship is also maintained because they know each other. In addition, a firm can acknowledge the possibility of receivers' competitiveness in the future.
3. *Production capability* – similar to the above criteria, a firm prefers distributing to receivers where produce no defective products. This is meant to using good quality of machines and raw materials. The ability to increase productivity is also necessary in case of emergency. Likewise, receivers must have ability to alter production process in order to suit with the change of customer orders. These production capabilities help to reduce customer satisfaction impact.
4. *Financial capability* – this capability is concerned when risk receivers need to invest for extension their production line. Additional investment allows receivers set up their production process and standards similar to distributors'. In addition, amount of turnover per year is highlighted to understand cash flow and cash circulation of receivers and that avoids the probability to bankrupt.

5. *Manpower capability* – risk receivers must have skill/experience to satisfy distributors' requirement. Skilled staff is necessary to reduce defective work and save from harmful task. So, high skilled labour can gain more trust than the less one.
6. *Reputation to manage the risk* – ability of risk management is surely important to justify for capable risk receivers. A firm considers reputation to manage the risk from historical record, contingency plan establishment, and customers. Likewise, previous experience of managing the risk allows a firm to acknowledge.
7. *Budget* – this is true for automotive business. Every process is limited by budget. A firm selects to distribute to receivers who can operate with budget set. This prevents the impact to higher cost of end product and surely not to further impact the other supply chain process.
8. *Relationship* – this is another important factor to select risk receiver. Actually, relationship would not be highlighted for capability. However, relationship makes a firm feel more comfortable when distributing the risk to. A firm always distributes to where is closer relationship. On the other hand, closer relationship makes receivers sincere to accept the risk being distributed.
9. *Communication* – similar to above criteria, good communication allows receiver feel free to accept the risk. A firm always spreads the risk to receivers where are easy to talk with. Furthermore, quick learning culture of receivers is also recognised.
10. *Less bargaining power* – this is true that a firm always distributes the risk to less bargaining power receivers. Less bargaining power brings to have less negotiation power. Then, firms can force receivers to receive risk being distributed.

From findings, the respondents indicated that once receivers understand rationale why a firm selects them, the conflict is truly reduced. In addition, trust is a key enabler for firms to select risk receivers against aforementioned criteria.

## **DISCUSSION WITH PRIOR WORK**

With reference to the proposed framework of risk distribution strategy (Yingvilasprasert & Banomyong, 2010), three decision-making factors were extracted from the literature. Figure 1 hereunder presents the proposed framework. It was developed from common texts in different disciplines (such as Medical science, Legal and Fiancial field). The common texts only provided more details why this factors should be comprised for risk distribution straegy. Without investigating in supply chain practice, it therefore lacks of empirical evidences.

Figure 1: Proposed framework for risk distribution strategy  
*Source: Banomyong & Yingvilasprasert (2010)*

The findings from this research work therefore fill the research gap. Three factors, found from interview process, are related to distributor, risk, and risk receiver. However, the empirical findings provide more insights by specifying how each factor would be. First, not only lacking of risk control ability, the possibility to reject the risk was found to be risk distributor's rationale. Second, risk selection is deeply specified for suitable characteristics. Third, practical characteristics of risk receivers were provided. Renaming the factor is advised for more understanding for both further study and practice.

## **CONCLUSION AND FURTHER STUDY**

Three decision-making of risk distribution strategy are found from the study. First, risk distributor's rationale was extracted due to the fact that risk distributor is the one who start risk distribution process. Second, risk characteristics were found from normal practices to select risk management strategy. Matching risk with the most appropriate

strategy can deliver the successful of risk mitigation. Third, characteristics of risk receivers were established because there is a need to have someone receive the risk being distributed. Risk receivers here were very important because they would conduct risk treatment after risk distributor distributes the risk out. Selecting the most capable receivers therefore prevent return future loss and impact through the supply chain. The findings from this empirical study is different from the findings of the previous research. Thus, this research work provide so meaningful to academic researchers and practitioners.

Knowing these three decision-making factors lead academic researchers understand more insights of risk distribution knowledge and that will be benefit for their further study. Furthermore, business practitioners will understand which factors impact to risk distribution process and that they can deliver the success of risk distribution implementation. This study has limitations which may lead to further study. First, survey method is required to validate this exploration. Second, investigating in other industries are required to validate for generalisation.

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## Section 4 – Supply Chain Performance and Assessment

### CORPORATE MEASURES IN ESTABLISHING RESILIENT LOGISTICS SYSTEMS

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#### ABSTRACT

This paper will examine the steps that Japanese companies have taken since the Great East Japan Earthquake to address the risks relating to their logistics systems, and the current status of these measures. Specifically, it will systematically examine measures taken to create backup or alternative logistics systems, including the use of more than one supplier, the establishment of redundant logistics facilities, geographical diversification and dispersal of factories, and the accumulation of surplus inventory. To develop truly resilient logistics systems, it is essential that companies cooperate with one another to establish complete supply chains which address the risks on an industry-wide, or even economy-wide basis.

#### 1. Introduction

Following the Great East Japan Earthquake, a number of problems were identified related to Japan's logistics network. Supply chains were disrupted, cutting off the supply of raw materials, parts and finished products needed by manufacturers, forcing them to halt production activity, and creating shortages of many products in retail stores. Following the quake, companies became keenly aware of the importance of addressing risks related to their logistics systems, and many took steps to revise these systems. Another major quake is bound to happen eventually, and while steps are being taken to address the risk, existing stockpiles of goods in publicly sponsored "strategic reserves" are likely to be inadequate. The private sector must step in when emergencies strike, to procure needed items and ensure an adequate supply. Corporations have an extremely vital role to play in ensuring the supply of vital goods in times of emergency, so it is important for them to establish systems of supply that can address these risks.

This paper will look at the logistics strategies and strategic revisions to the supply chain that companies have adopted since the Great East Japan Earthquake, consider how much progress has been made, and try to identify the degree to which logistics risks have been addressed. Specifically, it will examine the steps taken at each level of the supply chain – procurement, production, wholesaling and retailing – and categorize the type of measures taken, including diversification, in-house production, accumulation of inventory, transparency, creation of alternative or back-up systems, common use and standardization, and improved resilience. Furthermore, since it is difficult for each individual company to respond adequately to natural disasters of this sort, we will look at the importance of cooperation and mutual measures to build logistics systems that will improve the resilience of the overall supply chain.

In considering ways to develop resilient logistics systems, one of the first points that became apparent after the March 2011 disaster was that the effort to develop efficient, lean supply chains (lean SCM) was counterproductive. A great many papers and studies have addressed the need for flexible, redundant and resilient logistics systems (Christopher, 2004, Sheffi, 2004, Manuj and Mentzer, 2008). Furthermore, with respect to the development of information systems, many papers have examined the importance of comprehensive systems that cover the entire supply chain (Hanifan, 2007, Wagner and Bode, 2008, McCormack and Handfield, 2008). Existing papers that discuss measures taken by companies to deal with logistics-related risk, in the wake of the earthquake and tsunami, have been based on an analysis of questionnaires, and particularly surveys of the steps

taken to adjust procurement methods (Uehara, 2012). A number of magazine articles have also appeared, dealing with specific examples of steps taken by a particular company (Nikkei information strategy, 2011, Logi-biz, 2011, Nikkei business, 2012). This paper uses the information collected from individual company interviews as well as data from existing newspaper and magazine articles, to identify and classify the types of measures that companies have taken and determine the current status of these measures. While most of the information deals with measures taken by individual companies, the paper will also discuss the importance of joint, cooperative efforts to address the overall supply chain.

## **2. Logistics-Related Risk Management Measures and the Great East Japan Earthquake**

The Great East Japan Earthquake had a massive impact on Japanese companies in terms of the way they perceive and respond to risk. There has been a dramatic change in the way that companies view their logistics contractor, since the disaster. Surveys of the factors that companies consider when choosing a logistics supplier (Japan management association, 2011), conducted before the earthquake and after the earthquake, illustrate this change. Before the disaster, the priorities listed by survey respondents included price (mentioned by 75.8% of respondents), quality and timeliness (67.3%) and functionality (60.7%). Following the quake, quality and timeliness had become the most common factor mentioned (60.8%) while safety and security rose to 50.9% (from 36.2%) and company continuity increased to 45.7% (from 21.7%). Price, by comparison, dropped to third place in importance, at 47.4%. While price had formerly been viewed as the most important factor, following the quake companies came to view risk management issues and energy savings as the most important selection criteria.

There have also been changes in attitudes towards production and distribution locations. Prior to the earthquake, companies were consolidating their activities in a single location, for reasons of efficiency. Now, however, companies are looking to disperse their operations. Since the disaster, some 40% of companies have begun to reconsider the location of production and distribution facilities. This shows that Japanese companies have changed their standards for evaluating a logistics supplier, significantly, since the earthquake.

## **3. Changes in Supply Chain Management (Procurement Logistics)**

Following the Great East Japan Earthquake, Japanese companies have begun to implement changes in their approach to supply chain (procurement) logistics, and to their manufacturing structure and logistics systems. The following examples of new trends or changes were noted, based on company interviews, newspaper and magazine articles.

### **3.1 Clearer identification of suppliers**

An increasing number of companies have taken steps to clearly identify the initial source of all items procured from suppliers. For example, Toyota Motor Corp. has asked all primary suppliers to provide them with a full, detailed diagram showing the sources of all items, in some cases extending to sixth- or even seventh-level parts or materials suppliers. This information on the overall supply chain is stored in a database at each Toyota factory. The company makes inquiries about each part or product, and whether there is an alternate factory or facility that can make the same product if the first-choice factory is closed due to some disaster. Parts that can only be provided by one factory or location, are then identified as "parts at risk".

### **3.2 Diversification of suppliers and distribution routes**

There are clear indications that companies have begun to diversify their suppliers and establish multiple or alternate supply routes. For example, since the late 1990s automakers have been gradually reducing the percentage of any individual product that they procure from a single primary supplier, and establishing multiple procurement routes. However, they still are often reliant on a small number of secondary or tertiary suppliers for a given item. Therefore, they have begun asking primary suppliers to diversify their sourcing and to ensure that they procure every item from at least two different suppliers.

### **3.3 Use of common or standardized components**

Automakers and electronics manufacturers, among others, have made considerable progress in standardizing components or using the same components in a variety of models. Toyota Motor, for example, has changed the design of specialized components and to the greatest extent possible, it has switched to the use of standard parts in car models, even to the point of unifying the design process for components worldwide. About half of all the components that Toyota sources from other vendors will be standardized products used in multiple models. Honda Motor Co., Ltd. has also made progress in standardizing its components. Some 80% of the parts used in Honda's small bikes are purchased in bulk from about three suppliers.

### **3.4 Increasing local procurement**

Companies are reconsidering the procurement of parts from distant suppliers, and trying to increase the percentage of locally sourced items. For example, Toyota Motor has stopped supplying materials and partially-assembled components from Japan to overseas factories, and is instead trying to source 100% of the parts in its vehicles from local suppliers.

### **3.5 Asking suppliers to increase inventories**

Many companies have begun to increase inventories of parts and supplies, not only by raising the in-house stockpile, but also by asking suppliers to reconsider their inventory levels. In the case of items that are difficult to produce at alternative plants, such as electronic components and cast metal items in particular, they are asking suppliers to maintain inventories at levels that would ensure a supply of these items is available even if the plant that makes them is temporarily closed.

## **4. Changes to the Manufacturing Structure**

Examples of changes that companies have made to their manufacturing structure include: dispersal of production facilities, the establishment of alternative production sites, a shift of contracted production activities to in-house facilities and changes in the location of production sites.

### **4.1 Dispersal of production facilities**

In recent years there has been a tendency for manufacturers to concentrate their production facilities in the same region. This not only included reductions in the total number of factories but also the location of multiple factories in the same geographic region or area. Even companies with multiple factories often concentrated production of one particular product at one particular facility. This consolidation process helped to improve production efficiency, but in case of an accident that closed a particular factory, it may have been impossible to move that plant's activities to another site. This could cause the entire production process to shut down. Following the Great East Japan Earthquake, a great many manufacturers have revised their production structures by dispersing production activities to numerous locations. Particularly in the case of important products, they have established separate facilities in eastern and western Japan, each capable of producing the same products.

#### **4.2 Establishing alternative production sites**

After the Great East Japan Earthquake, some manufacturers were able to quickly resume production even though their facilities in the eastern Japan were destroyed, because they had alternate sites to which they could shift production activity. Using these companies as an example, many manufacturers have begun to set up alternative production sites. For example Toto Ltd. – a manufacturer of ceramic sanitary fixtures – is setting up alternative factories in Japan at sites a considerable distance from one another, each making the same products.

#### **4.3 Shift to in-house production**

Although a large number of companies have taken steps to disperse production, there are other examples of measures to bring production in-house and consolidate activities. Pen manufacturer Zebra Co., Ltd. is planning to centralize production activity, based on the view that in-house production can be restarted more quickly. The company believes that the risk related to in-house production is less than that for dispersed, contracted production. In order to increase in-house production of its products for domestic market, it is reviving domestic production system. By internalizing and consolidating production, as well as centralizing distribution sites, the company hopes to reduce risk.

#### **4.4 Re-evaluating the location of plants**

In the past, both production facilities and distribution facilities tended to be concentrated along the seacoast, but following the tsunami, many manufacturers are reconsidering their plant locations. Some companies are shifting facilities from coastal sites to more inland locations. For example, Suzuki Motor Corp. is transferring a development facility from its current location on the coast to an inland site. Kawai Musical Instruments Manufacturing Co., Ltd. is also shifting some functions from its current factory site on the coast to an inland location.

### **5. Revising Logistics Systems**

Some of the changes that companies have made to their logistics systems include a wider dispersal of distribution centers, establishment of alternative distribution sites, increases in the inventory stockpile, automation and revisions to automated systems, revisions to the transport system and the establishment of backup information systems. Examples of these measures are outlined below:

#### **5.1 Dispersal of distribution centers**

In the past, the main trends in logistics involved consolidation of facilities and distribution functions, in order to reduce inventory size and improve operating efficiency. Since the earthquake, however, companies have begun to recognize the risk that consolidation invites. Many are now taking steps to disperse their distribution centers. Even companies that have already established large-scale distribution centers on the ring road system surrounding Tokyo have begun to set up other facilities to disperse distribution, particularly in inland sites that will not be affected by the soil liquefaction and subsidence seen in areas along the coast. In this way, they hope to reduce disaster-related risks.

Retailers also have been dispersing distribution centers. Since the earthquake, convenience store operators have been pushing for greater dispersal of distribution sites to reduce risk. For example, the company that supplies boxed lunches for Seven-Eleven Japan Co., Ltd. has set up several logistics centers, and introduced molding machinery to make rice balls more quickly and with higher quality.

## **5.2 Identification of alternate distribution centers**

Following the Great East Japan Earthquake, many distribution centers in the area were damaged and companies had to ship their products in from distribution sites in the Metropolitan area, or some other nearby prefecture. In order to adjust to such an emergency situation quickly and smoothly, it is important to identify specific “alternate centers” to take over for each center that is damaged.

One food wholesaler whose distribution center was unusable after the earthquake received purchase orders at its metropolitan area facility that were 2-3 times the normal size, and in some cases, up to ten times the typical amount. For the company’s 300 distribution centers in Japan, a business continuity plan was established that specified alternate sites for every process. If any center becomes unusable, or unable to handle the full required volume of activity, the continuity plan identifies the facility that is responsible for taking on that burden.

## **5.3 Accumulating inventories**

Under normal conditions, inventories can be reduced to very low levels without having an adverse impact on production or distribution activity. However, in times of emergency, when it is difficult to procure supplies, the ability of a plant to continue operating depends on the amount of raw materials or parts that are stockpiled in inventory. Furthermore, if production halts, the size of finished product inventories determines how long a company can continue to supply its customers. In the case of retailers, when shipments are halted by a disaster the size of inventory determines whether or not the store will have any products to sell.

Pharmaceuticals manufacturers, in particular, have begun to re-evaluate the size of their inventory stockpiles. One manufacturer doubled inventories of all products to ensure that, in principle, the company would have a six-month supply even if all production stopped. The six-month supply is intended to ensure that all demand can be met until the production line can be restarted. In addition, the company has taken steps to reduce risk by ensuring that in addition to its own distribution center, it can also use the distribution facilities of another manufacturer in another prefecture, in times of emergency.

## **5.4 Automation and changes to automated systems**

Following the Great East Japan Earthquake, many automated warehouses in the northeastern area in Japan ceased operation because machinery was damaged, or because the products stored in automated warehouses fell off the shelves, making the equipment useless. Particularly in small automated warehouses where items were tightly packed to save space, it took many days of human labor to get the facilities back into proper operation. In many cases, to ensure that it is possible to resume operations quickly following a disaster, forklifts and human operators have been re-introduced, often operating in parallel with the automated warehouse. Extremely important items have been relocated and are now sometimes stored in flat displays to reduce the disruption caused by an earthquake.

## **5.5 Revisions to transportation systems**

To reduce risk, joint transport activities are being introduced, and transport methods are being diversified. For example, Asahi Breweries Ltd. and Kirin Brewery Co., Ltd. have adopted a joint distribution system in parts of the Tokyo area. They intend to steadily expand the scale and the coverage area of this joint system. Following the March 11 earthquake, both companies’ plants were damaged and it was difficult to obtain vehicles or make deliveries to particular areas. The existence of jointly used facilities will help to reduce this risk. In addition, Kirin Brewery has begun using more rail transport to deal with problems caused when it was impossible to obtain fuel for delivery vehicles.

## **5.6 Establishment and improvement of backup information systems**

In order to return logistics facilities to normal operation, it is essential that the information system also be brought back on line. Some companies did not have backup data or servers for their information systems which were still usable after the earthquake. Therefore, many companies are now establishing alternative information systems and backup data at alternate sites. One manufacturer of daily household products had its main system and servers at a location in the earthquake zone, and following the Great East Japan Earthquake the system went down. The company has now set up a mirror information system in Western Japan, so that in case of a similar disaster in the future, the alternate site can continue to process customer orders and take over the data processing work.

## **6. Changes at the Individual Store Level**

Individual retailers are also taking steps to adjust, for example, with in-house production of some items, development of communications links and so on.

### **6.1 In-house production**

Following the Great East Japan Earthquake, many convenience stores encountered difficulty in obtaining a regular supply of food items. Some responded by preparing their own boxed lunches using other foods they had in stock. Ingredients were transported in from distribution centers in chilled or frozen form, rice was cooked on the store premises and boxed lunches were made inside the store, to meet the surge in demand that followed the earthquake. Some stores are now taking steps to make it easier to cook or prepare food items in the store, and thus respond to natural disasters or sudden changes in environmental conditions.

### **6.2 Development of communications links**

Following the Great East Japan Earthquake, it was very difficult to access communications networks and information systems. Even before the earthquake, one general merchandise store had satellite phones, FM broadcast transmitters or multi-channel access radio system at every one of its stores, and some executives or managers also had satellite phones at home. These proved to be invaluable. Some other general merchandisers also had at least one satellite phone in each store. In the future, they plan to increase the number on site, and establish redundant communications links for emergency use.

## **7. Developing Logistics Systems for a Resilient Supply Chain**

Figure 1 provides a summary of the measures that various companies have taken to address the risks related to natural disasters. It illustrates how companies have addressed risks for each element of the supply chain, procurement, production, logistics (logistics center and transportation) and retail store, with measures such as dispersal of activities, in-house operations, revisions to inventory levels, clarification and transparency, development of alternatives, common use, standardization, improvements to resilience, the backup of information systems, and so on.

However, all of the items mentioned above are limited to an individual company or group introducing new measures. If individual companies disperse operations, diversify suppliers, create alternate operations, handle work in-house, and increase inventory levels, all of these measures increase costs. Some companies – such as medical products and drug suppliers – have a real obligation to increase inventory levels and avoid shortages. However, if every industry were to increase inventories of every product it would have a negative impact on efficiency that is impossible to fully justify. The best way to reduce risk is not simply to

pursue redundancy in all things, but rather, to try to introduce the necessary systems to support a more flexible and resilient supply chain.

It will be difficult for individual companies or facilities to take all the necessary steps needed to ensure that there is a steady and adequate supply of the most essential goods, in times of emergency. Rather, companies need to work together to develop a more flexible and resilient supply chain. Each of the companies that make up the supply chain need to develop a shared understanding of what is needed to ensure the stability of the supply chain, then work together to introduce the necessary systems and policies. The necessary elements in this process are cooperation across company lines, support from outside the disaster area, the ability to access alternate or backup facilities, and the development of a transition process.

As a first preparatory step, members of the supply chain should identify the most essential items and the specific supply volume needed, and locate logistics facilities in appropriate sites to ensure that this is possible. Then they must identify the inventory amount, location, method of storage, means of obtaining alternate transport equipment and transport method needed to support the supply chain. Once such a system has been designed, simulations need to be conducted to determine the impact if multiple sites are affected, decide where to locate inventories, determine the time needed to resume operations, identify alternative systems and the time needed to put them into service, and identify and address any potential bottlenecks.

Figure.1 Risk countermeasures in supply chain

	Procurement	Production	Logistics		Retail store
			Logistics center	Transportation	
Dispersal of activities	Dispersal of procurement	Dispersal of factories	Dispersal of logistics centers		
In-house operation	Increase of local procurement	Self-manufacture			In-house
Revisions to inventory levels	Asking more inventories		Accumulating inventories		
Clarification and transparency	Transparency of procurement	Transparency of production	Transparency of logistics		
development of alternatives		Alternative production	Alternative logistics centers	Revision of transportation	
Common use, Standardization	Standardization of parts				
Improvements to resilience		Revision of factory location	Revision of automation		
Backup of information system		Backup of information system			Maintenance of information

If and when a disaster does occur, the entire supply chain must be able to share information on every aspect of activities including the extent of damage, recovery time, level of inventories, transport availability and so on, in order to procure and distribute supplies in an efficient manner. Immediately after the disaster, it is important to identify which elements of the supply chain are still functional, what inventories are available, and how they can be supplied to the necessary locations. When factories or distribution centers are not seriously damaged, the types of repairs needed and the supplies required to get back into full operation must be clearly identified so all members of the supply chain know when and how they will be able to obtain needed items. On the other hand, when factories or distribution

centers are seriously damaged, alternative sites and systems must be identified as quickly as possible. In addition, communication and cooperation are needed to ensure that the damaged facilities are restored to operation at the earliest possible date.

## **8. Conclusion**

Following the Great East Japan Earthquake, it became apparent that existing logistics systems were weak in the face of disaster-related risks. Since the disaster, companies have taken steps to revise their logistics systems and supply chains to address these risks. However, most of the responses up to now have been conducted at the individual company level. In order to ensure that there is a stable supply of the most important or essential items, following a disaster, it is necessary to adopt a systematic approach that aims to make the entire supply chain more resilient. The supply chain must be able to adjust and respond at each stage – from immediately after the quake to the initial response stage, and then the rebuilding stage – with speed and flexibility.

In the future, companies will need to evaluate their operations and try to determine the most efficient and appropriate measures to take, depending on their industry and characteristics of their products. By working together across the supply chain, companies can share the burden of cost to make these adjustments, share information on measures taken, and consider the use of jointly developed systems

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## **MATURITY MODEL FOR IMPROVING PROCESSES IN SUPPLY CHAIN**

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### **INTRODUCTION – BUSINESS PROCESS MANAGEMENT AND BUSINESS PROCESS MATURITY**

According to Oakland, all activities performed in companies, can be identified as processes. Process is defined as "a set of interrelated activities that transform inputs to outputs" (Oakland, 2004). Hammer and Champy indicate that the process is a set of actions with a specified input, which, as a result, produce an output bringing value to the customer (Hammer and Champy, 1993).

Worldwide research conducted among different types of companies (BPTrends, 2008; Wolf and Harmon, 2012) prove that organisations are increasingly becoming process oriented and perceive process management as a key factor of their operational and market success.

Simultaneously the concept of business process maturity has been introduced. The definition of maturity, depending on the source, may vary significantly. Initiator of the process maturity literature (Humphrey, 1987) defined process maturity as "the degree of explicit definition, management, measurement, control and effectiveness a process has". Maturity, with respect to processes, is also defined as the ability of the organisation and its processes to systematically provide better business results (Rosemann and De Bruin, 2005; Hammer, 2007).

Humphrey (1987) states that immature organisations lack with formal management, tend to improvise on processes, are reactionary and identify difficulties with meeting set deadlines. On the contrary, mature organizations, possess accurate documentation of processes and work activities, which are executed according to planned processes. Furthermore Humphrey (1987) states that "maturity implies a potential for growth in capability and indicates both the richness of organization's processes and the consistency with which it is applied to projects throughout the organization".

A framework that is widely adopted in practice is the Capability Maturity Model (CMM), developed by the Software Engineering Institute (SEI)/Carnegie Mellon University (Humphrey, 1987). Initially, the CMM was developed for the maturity assessment of software development processes, however later it was found to be applicable in other industries and processes. The CMM classifies business processes into five subsequent "maturity levels", which became a standard framework for process maturity classifications.

### **BUSINESS PROCESS MATURITY MODELS**

One of the observed trends in business practice is the development and interest in the so-called Business Process Maturity Models (BPMM). They can generally be characterized as sets of recommendations and good practices that enable obtaining operational efficiency of processes. In most of the cases these models as a starting point determine the existing state of process management (called "as-is" state), while the aim of their application is to achieve a certain, future state of process management in the organisation (called "to-be" state). The improvement path is often described through maturity levels.

The most popular maturity model (CMM) developed by Software Engineering Institute/Carnegie Mellon University was changed over the time into CMMI - Capability

Maturity Model Integration (Humphrey, 1995). The first version of CMMI was published in 2002, second in 2006, and currently valid edition was developed in November 2010. Other models that can be used for process maturity assessment and are often cited in literature are maturity models developed by McCormack, Johnson and Walker (2003), Lockamy and McCormack (2004), Fisher (2004), Rosemann and De Bruin (2005), as well as PEMM - Process and Enterprise Maturity Model (Hammer, 2007), BPMM - Business Process Maturity Model (OMG.org, 2008).

According to available studies about 150 different models of processes maturity can be identified (Spanyi, 2004; Kalinowski, 2012). Most of them are based on CMM framework, but also concept of achieving and measuring the effectiveness of the organisation formulated by Rumller and Brache (Rumller and Brache, 1990).

**BUSINESS PROCESS MATURITY OF POLISH COMPANIES – RESULTS OF THE RESEARCH**

The studies presented in the paper were conducted during November and December 2011. The main selection criteria to the research sample was ISO 9001 quality management system certification Data was obtained from the database published by HBI Poland Ltd. Research questionnaire was sent to 3224 organisations and 174 correctly completed questionnaires were returned and included in the research sample (return rate was 5,4%).

In order to present the result of the research in a structured way, a model of process management methodology implementation is introduced below. Each of the framework’s levels represents a set of activities required for process management implementation and simultaneously a certain maturity level.

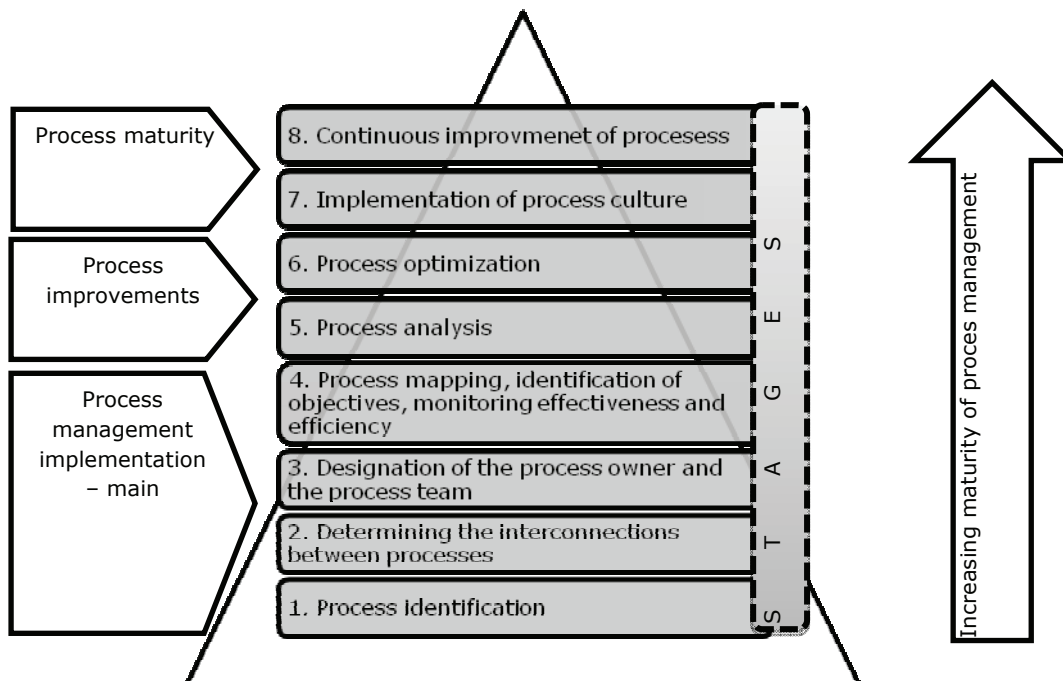


Figure 1: Process management implementation/maturity model, source: own elaboration.

The research focused on establishing the adoption level of selected activities typical for the process management methodology implementation.

<b>Stages</b>	<b>Selected activities of process management</b>	<b>Share</b>
1	All operational processes have been identified	62,07%
	Main operational processes have been identified	58,05%
	Main management processes have been identified	57,47%
	Main supporting processes have been identified	52,30%
	Processes performed (partially or integrally) by external organisations have been identified	40,23%
	All supporting processes have been identified	34,48%
	All management processes have been identified	29,89%
2	A process map / process management model is established for the organisation	96,55%
	The processes are linked with the organisational structure – the units responsible for performing processes are indicated	83,33%
	The organisation uses a matrix (process vs. functions) organisational structure	71,84%
3	The process owners are designated and their responsibilities are defined	96,55%
	The responsibilities of the process team are defined	90,80%
	There is a function / person responsible for coordination of process management	82,76%
4	The targets and indicators for identified processes are established	93,10%
	The skills and competences required for process realisation are established	83,33%
5	The employees directly involved in process realisation can submit proposals for process improvement	85,06%
	The company uses tools for process analysis and improvement	73,56%
	The identified processes have cost-driven factors established and they are used for process management	62,07%
	The company uses external benchmarking for process improvement	40,23%
	The sources of inefficiency in processes are systematically identified and eliminated	39,66%
	The company uses Lean and Six Sigma methodology for process improvements projects	33,91%
6	The company uses software for analysis, description and improvement of processes	62,64%
	The implemented improvement projects include many organisational units or the whole organisation	59,77%
	The implemented improvement projects focus on single processes or organisational units	55,17%
7 & 8	The process owners use the measurement data for process and change management	78,74%
	The decisions regarding the whole organisation take into account process results	77,59%
	The employees are trained in process improvement	74,71%
	The process owners are trained in process improvement	73,56%
	The company established specialized teams (centres of excellence) involved in process improvement	35,06%

Table 1: Selected activities of process management performed by the surveyed companies – results of research, source: own research.

## **CONCLUSIONS – LIMITATIONS OF THE SURVEY AND FUTURE RESEARCH**

According to the presented research results it can be stated that Polish companies holding ISO 9001 certificate represent relatively high level of process maturity. Shares of companies declaring the selected process management activities took place were relatively high and mostly exceeded 50%, while in over half of the cases the shares were closer to 80 – 90%. The limitation of the study may be the fact, that most of the questionnaires (over 61%) were filed by companies of at least medium size (employing over 51 employees), in which, due to the scale of operations, more developed approach to process management could be used. Another distortion of the study might be that, the questionnaires could have been returned primarily by companies in which the process management procedures operated properly, whereas the organisations that encounter obstacles in applying the principles of process management efficiently (although being certified for ISO 9001 compliance), might have ignored the request for completing the survey. The described studies were a preliminary research used in application for a Polish National Research Centre grant. The current research project focuses on analysing different maturity models, their dimensions and characteristics. Upon this study an extended list of activities specific for different maturity levels and process management dimensions is being prepared. The developed framework will be subsequently used for a more thorough assessment of process maturity in Polish companies.

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## **SUPPLY MANAGEMENT CAPABILITIES: PROCESS EVALUATION AND STRATEGIES FOR COST RATIONALISATION IN SMES**

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### **ABSTRACT**

Small and medium scale enterprises (SMEs) are generally perceived as firms with rather low supply management capabilities compared to large firms. The application of supply management tools and techniques to enhance their capabilities is quite rare among SMEs. Purchasing portfolio models have been widely accepted as one of such advanced techniques in professional purchasing to enhance capabilities in supply management. In this regard, Kraljic's (1983) purchasing portfolio matrix has received much attention among both academics and purchasing practitioners. This paper presents a case study of a manufacturing SME focusing on its supply management activities. The case illustrates how to assess and improve the supply chain performance of a low-volume manufacturing SME with high raw materials costs. The study focuses on improving supply management capabilities by evaluating supply processes and strategies through the application of Kraljic's purchasing portfolio matrix. Key findings confirm the low purchasing status in SMEs, hence low supply management capabilities. Following the application of the Kraljic's Portfolio Matrix, supply management strategies have been proposed for rationalising purchasing cost and enhancing the firm's supply management capabilities.

**Keywords:** Supply management capabilities; purchasing portfolio matrix; cost rationalisation; supply chain; performance measurement; SMEs.

### **1. INTRODUCTION**

Crook and Combs (2007) state that purchased inputs can take up to 75% of a firm's cost of operations. Kannan and Tan (2002) contend that rising cost of business operations calls for effective supplier management. An efficient supply chain is conceived as a key competitive variable in the 2000s (Cousins et al., 2006). Many firms, particularly large ones, have given their purchasing function a makeover from one of mainly operational and tactical support to a status with a status of strategic capability. However, the view still pertains that in many SMEs the purchasing function is either under-developed or non-existent. It is not surprising that studies have found that the majority of small firms perceive purchasing as unimportant. There exists a low formality of purchasing in small firms (Pressey *et al.*, 2009; Ellegaard, 2009). Not only is purchasing informal in most SMEs, but also reactive in nature (Ellegaard, 2009; Arend and Wisner, 2005). The apparent lack of appreciation for the purchasing function among SMEs forms the foundation for this study. The research is a case study of a manufacturing SME. It constitutes a practical effort to address challenging purchasing issues and discover opportunities for enhancing the supply management capabilities of the case company. The study employs a purchasing portfolio approach to rationalise the purchasing spend. The potential of how purchasing improvements can contribute to a company's competitive advantage is widely recognised in the literature (Dubois, 2003; Caniëls and Gelderman, 2007).

## **2. LITERATURE REVIEW**

Supply management involves “managing a portfolio of relations, differentiating between different types of relations and adjusting relations to different situations” (Bakker and Kamann, 2007:304). Gelderman and Van Weele (2003) for example argue that all products and buyer-supplier relationships do not require the same level of attention. The value of a supplier is very much determined by the extent to which the buyer depends on him. Thus suppliers require different types of relationships in order to manage them. This suggests that appropriate relationship strategies must be designed to deal with various product categories in order to optimise relationship benefits. The need for a differentiation approach to buyer-supplier relationship management has resulted in the emergence of purchasing portfolio models.

### **2.1 PURCHASING PORTFOLIO MODELS**

Products vary in the extent of their criticality to the buyer. Whereas some products or suppliers can easily be substituted, others cannot at least in the short run. The extent to which a buyer depends on the supplier suggests the level of criticality of the supplier and determines the power balance and interdependence between the buyer and the supplier. Caniëls and Gelderman (2007) maintain that the interplay of concepts such as power and interdependence are important for understanding buyer-supplier relationships. Not only are these concepts important for understanding buyer-supplier relationships but they are key factors in developing purchasing strategies. The analysis of power and interdependence in buyer-supplier relationships forms the core purpose of purchasing models. Portfolio models are useful tools that support strategic decision making relating to resource allocation decisions. These models employ the concept of segmentation in designing supply relationship strategies for different product groups. A purchasing model categorises purchasing situations and prescribes required actions under varying situations. Purchasing portfolio models generally aim at developing differentiated purchasing and supplier strategies to exploit buying power (Gelderman and Van Weele, 2003). The implication of the models is a differentiated purchasing behaviour for various product groups and purchasing situations based on the balance of power and dependence between the buyer and the supplier. The fundamental assumption underlying purchasing models according to Dubois and Pedersen (2002) is the existence of differences in power and dependence between the exchange partners. A dominant purchasing model which many other models have extended is the work of Kraljic (1983). Kraljic’s model first appeared in the Harvard Business Review in 1983 and has become the foundation of many other purchasing models. In spite of the further work that has been undertaken on Kraljic’s model since its emergence to address the model’s limitations, it still remains a significant influence on the purchasing profession and a very relevant decision making tool for supply management professionals.

### **2.2 KRALJIC’S PURCHASING PORTFOLIO MODEL**

The first comprehensive purchasing portfolio model was developed by Peter Kraljic. The seminal paper of Kraljic which was titled “Purchasing must become supply management” appeared in the September 1983 edition of the Harvard Business Review. Kraljic was the director of an international consulting firm, McKinsey & Company, Inc based in the firm’s Düsseldorf office when the paper was published. Caniëls and Gelderman (2007) state that supply management professionals especially in Western Europe have widely recognised and adopted Kraljic’s portfolio matrix. Kraljic’s portfolio matrix has a dominant influence on purchasing strategy for many firms across different industrial sectors (Gelderman and Van Weele, 2003; Lamming and Harrison, 2001). The outcome of the model is a strategy to minimise supply risk and maximise buyer power. The model enables purchasing professionals to appreciate their firm’s weaknesses and strengths with respect to suppliers and puts forward a strategy to manage suppliers.

Kraljic's model is represented by a 2x2 matrix classifying products on the dimension of profit impact and supply risk resulting in four separate quadrants in the matrix (see Figure 1). The two dimensions are assessed on the categories of high and low. Each of the four quadrants contains one of the four product groups categorised by Kraljic: bottleneck products, non-critical products, leverage products and strategic products. The matrix proposes that every quadrant and the product groups contained within require a distinctive approach towards suppliers (Dubois and Pedersen, 2002). The classification of materials into the quadrants requires specific task, supporting information, and level of decision making. The non-critical group requires product standardisation, order volume monitoring/optimisation, efficient processing and inventory optimisation.

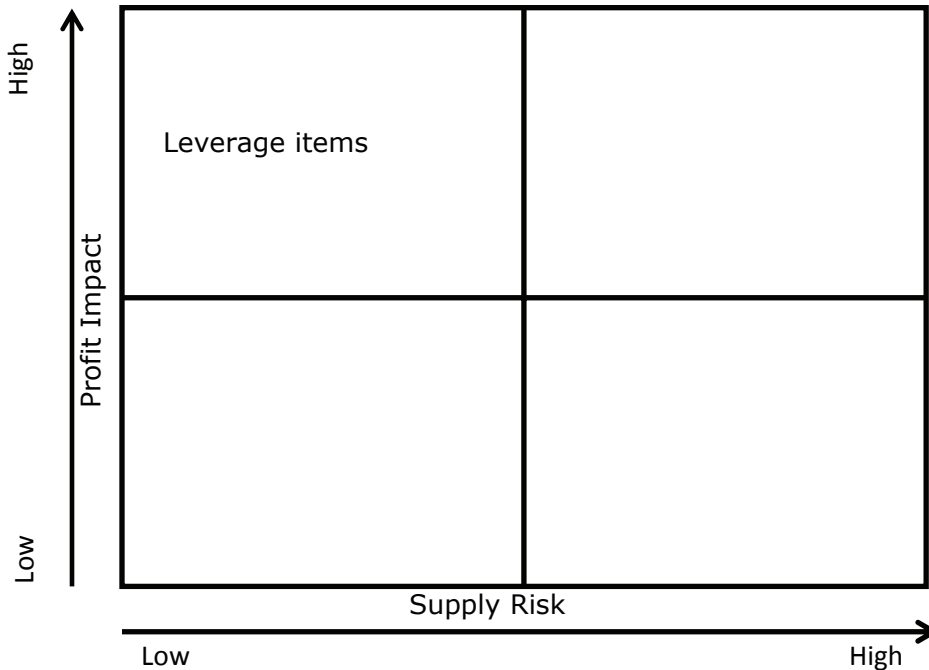


Figure 1: Kraljic's Portfolio Matrix (Kraljic (1983))

Decision making for non-critical items is at the lower level whereas good market overview, short-term demand forecast, economic order quantity inventory levels are the supporting information required. Main tasks required for leverage items include exploiting buying power, vendor selection, product substitution, targeted pricing strategies/negotiations, contract/spot purchasing mix and Order volume optimisation. Decision making is at the middle level. Good market data, short-to-medium term demand planning, accurate vendor data and price/transport rate forecasts are the supporting information required. Bottleneck items cause significant problems and risks. Tasks required on this product group include volume insurance, vendor control, security of inventories and backup plans. Decision making could take place at the top or middle level. Medium-term supply/demand forecasts, good market data, inventory costs and maintenance plans are necessary information needed for analysis. On strategic items, detailed market data, Long-term supply and demand trend information, good competitive intelligence and industry cost curves are necessary decision support information. Decision on strategic items is required to be taken at the top level. Some of the key tasks on strategic items include accurate demand forecasting, detailed market research, long term supply relationships, contingency planning and risk analysis (Caniëls and Gelderman, 2007; Gelderman and Van Weele, 2003; Kraljic, 1983).

Kraljic (1983) maintain that the interplay between supply and demand can shift product groups from one quadrant to the other, hence the need for portfolio analysis to be regularly updated. Kraljic (1983) emphasise that depending on the balance of power between the buyer and the supplier, a buyer may employ three distinct purchasing strategies of exploit,



balance and diversify. Caniëls and Gelderman (2007) explain that exploitation is the option in the case of buyer dominance whereas balance is appropriate in the case of a balanced relationship. The diversification strategy counters the case of supplier dominance. In spite of the popularity of Kraljic's model, a number of issues and concerns have been raised. Critiques argue that measurement of dimensions and variables appears to be the Achilles' heel for Kraljic's model (Gelderman and Van Weele, 2003; Dubois and Pedersen, 2002). These criticisms notwithstanding, Kraljic's matrix still remains an influential guide in purchasing strategy development.

### **2.3 SUPPLY MANAGEMENT CAPABILITIES (SMCs)**

Bowen *et al.*, (2001:176) defined SMCs as a "bundles of skills and resources that are developed through a strategic supply approach". Six capabilities have been synthesized from the literature. These include: 1) long term collaborative relationships with suppliers (Chen *et al.*, 2004; Bowen *et al.* 2001); 2) promotion of open communication between exchange partners (Chen *et al.*, 2004); 3) integration between supply strategy and corporate strategic objectives (Carr and Smeltzer, 1997); 4) Close working relationship with limited number of suppliers (Chen *et al.*, 2004); 5) Application of information technology in supply management (Paulraj *et al.*, 2008); and 6) highly skilled and empowered purchasing staff (Cousins *et al.*, 2006). Capabilities in supply management contribute significantly to enhancing not only the quality of a firm's products, but also ensure on-time performance, reduces time to market, enhances cost-efficiencies which results in the creation of a flexible and reliable manufacturing system (Bernardes and Zsidisin, 2008). However, the extent to which UK manufacturing SMEs possess these supply management capabilities has not really been investigated. The study sought to assess the case company on the basis of these six capabilities and applied Kraljic's model to develop strategies to enhance the firm's capability status.

### **3. THE CASE STUDY**

The case company is a low volume manufacturing SME with high material costs (approximately 95% of production cost) in the health sector. Effectively, the company basically assembles costly parts. These parts are often meant for other applications/industries where there is a high volume demand. Because of the bespoke nature of the critical components and the low demand for them, the company more often than not pays premium prices. The situation leaves the company vulnerable to some suppliers who sometimes subject the company to interruptions in material supply thus leaving the company exposed. As a result of the very low volume demand for the company's finished products, attempts have been made over the years to diversify into several other product ranges thereby compounding the problem of low volume, high variety input requirement from suppliers. With relatively low sales volume at the time of this research, the high material cost content presents a cash flow control challenge and has significant impact on profitability. The company's ordering procedures have also been described by the managing director as ineffective and old-fashioned. The study was therefore an attempt to address the supply management concerns raised above and ultimately to improve the company's capabilities in supply management.

### **4. RESEARCH APPROACH**

Using a case study approach, the methodology adopted involved a five-phase evaluation process. These include Characterisation of the company, purchasing process diagnosis, literature review, assessment of capabilities in supply management and selection of cost improvement strategies. This evaluation process as depicted in Figure 2 was adopted from Alarcón *et al.*, (1999).

#### **4.1 PHASES IN THE METHODOLOGY**

Details of activities which transpired at the various phases of the methodology process are described below.

## PHASE I: CHARACTERISATION OF THE COMPANY

This phase captured the understanding of the case organisation's operations. Information was sought on the company's niche market, product lines and how these are reflected in the management of supplies. Data for this purpose were gathered mainly through interviews, interactions, observations and filed records

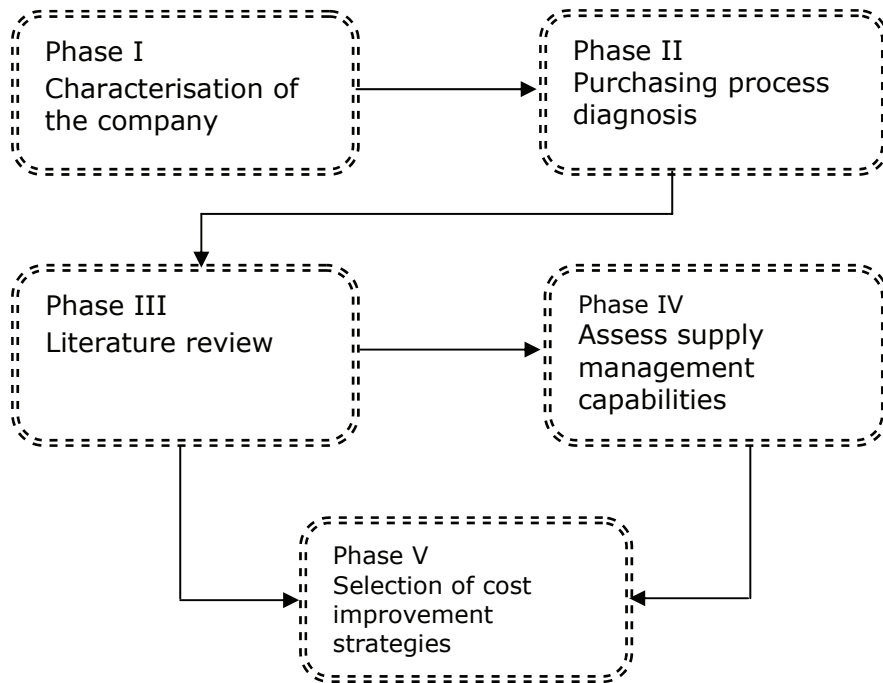


Figure 2: Project evaluation process adopted from Alarcón *et al.*, (1999)

## PHASE II: PURCHASING PROCESS DIAGNOSIS

In this phase, the purchasing process and activities of the company were thoroughly examined. Details of purchases values and the supplier base were established. Some of the key activities assessed include purchasing procedures, persons involved in purchasing, sourcing and selection of suppliers, and supplier base relationships. This phase enabled purchasing to be process mapped and was useful in ascertaining the potential sources of waste. Again it was helpful for identifying opportunities for cost improvement. Data collection methods used include interviews, observation and documentary analysis.

## PHASE III: LITERATURE REVIEW

This phase reviewed the supply management literature for acceptable standards and best practices. A comprehensive literature analysis was carried out based on the issues that emerged from the diagnosis of the firm's purchasing process. Purchasing portfolio models, particularly Kraljic's product portfolio matrix were visited to provide understanding for determination of appropriate supply strategies for different product requirement.

## PHASE IV: ASSESS CAPABILITIES IN SUPPLY MANAGEMENT

In this phase, a set of six capabilities in supply management resulting from the authors' previous analysis of the literature were applied. The six capability criteria formed the basis for assessing the company's supply management strengths. This was intended to highlight the gaps in capabilities and enable appropriate strategies to be recommended. Interviews and observations were used in the assessment.

## PHASE V: SELECTION OF COST IMPROVEMENT STRATEGIES

This phase of the methodology synchronised the literature review with the empirical data. Kraljic's product portfolio matrix was applied which resulted in the categorisation of the purchased inputs of the case organisation into product groups. Based on the categorisation, appropriate supply strategies were proposed intended to cut supply cost, eliminate waste and enhance the company's supply management capabilities.

### 5. ANALYSIS AND RESULTS

The analysis of data revealed that the case company was more focused on the customer-end of the business as is the case in many SMEs. The supply side of business even though very critical to its very existence, has not received the required attention; "...so looking at the supply side of things, its ever so important but not something we've done very well", one respondent remarked. The analysis of a twelve month data on purchase invoices and sales revenues shows that some 62% of annual sales revenue constitutes the annual purchasing spend. The obvious lack of attention on the supply side of operations was found to be a factor of human resource deficit and a prevailing perception among staff that the company has low buyer power due to its low volumes of demand.

*"...the fact that we have no buyer power, the fact that we are busy seeming to do something else....if you look at the human resources, nobody really in our company has that type of mentality, so it is a human resource deficit. We have nobody who has the mentality, the type of skills that is capable to do that sort of thing. The administration is not strong on the supply side of the business so it probably reflects the fact that I feel very weak in terms of dealing with, so I'll probably not bother and just let it go".*

Contrary to the position in the literature that supply management is usually the preserve of owner-managers in small firms (Morrissey and Pittaway, 2004; Pittaway and Rose, 2006), the responsibility for purchasing in the case company was split among five different members of staff as an adhoc administrative duty. The evidence supports the claim in the literature that generally there is low formality of purchasing in SMEs (Pressey *et al.*, 2009; Ellegaard, 2009). The company seems to have good working relationships with its suppliers. Even though the relationships took on a transactional and informal approach, adequate documentation was observed. The company's supply management capabilities were however found to be generally as seen in Table 1.

Supply management capabilities	Status
Creation of long-term collaborative relationship with suppliers	Low
Open communication between exchange partners	Medium
Close working relationship with limited number of suppliers	High
Integration between supply strategy and corporate strategic objectives	Low
Application of information technology in supply management	Low
Highly skilled and empowered purchasing staff	Low

Table 1: Assessment on supply management capabilities

#### 5.1 APPLICATIONS KRALJIC'S PORTFOLIO MATRIX

The purchases of the case company were categorised into product groups on the basis of supply risk and profit impact potential (see Table 2).

Product category	Code	Supply risk	Profit impact
Mechanical components	Mech	high	low
Electrical components	Elect	high	high
Polypropylene materials	Poly	low	high
Plumbing materials	Plum	low	high

Fibre glass products	Fibr	high	high
Wood	Wood	low	low
Packaging materials	Pack	low	low
Customised metal (steel/non-steel) frames and plates/sheets	Cust	high	low
Fasteners	Fast	low	low
Cushion and PVC materials	Cush	low	high
Factored products (Items for retail)	Fact	high	high
Marketing and publicity products	Mark	low	high

Table 2: Categorisation of purchased materials

Supply risk was assessed on the variables of availability of the materials, country of origin (whether prone to government instability and natural disasters), supplier accessibility and availability of delivery logistics. Profit impact was assessed on contribution of the product group to output, purchase spend, and impact on quality. The product categorisation resulted in the purchasing portfolio matrix in Figure 3. This model formed the basis for subsequent strategies that were proposed to enhance the supply management capabilities of the firm. A critical evaluation of the purchasing spend reveals a potential for cost savings projected between 1-5%. The annual sales revenue of the case organisation was estimated at £3m out of which £1.9m constitutes the annual purchasing spend, representing 62% of the sales revenue. It is anticipated that the proposed strategies will lead to efficiencies in the supply side of the business. If these strategies results in 1-5% cost savings of the purchasing spend as projected, this could potentially contribute at least £19,000 or some £95,000 directly to the bottom line annually.

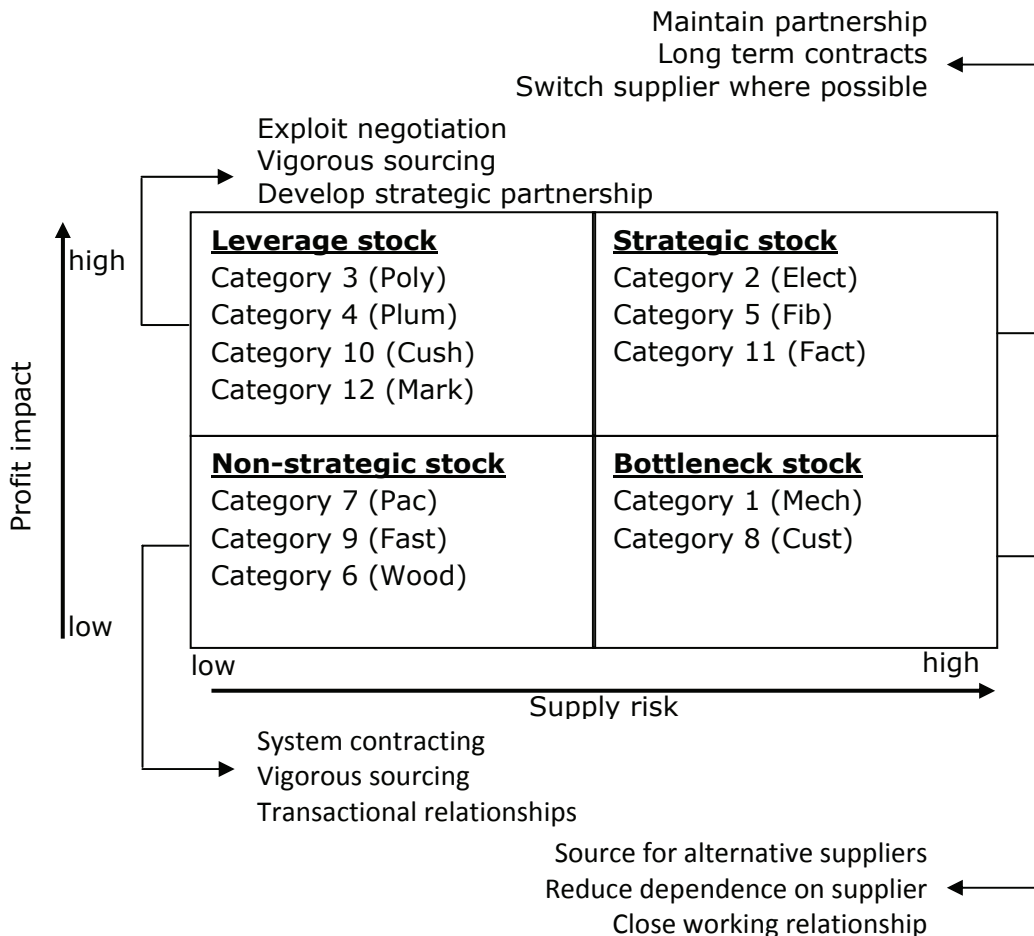


Figure 3: Purchasing portfolio matrix for the case study organisation

## 6. CONCLUSIONS AND PRACTICAL IMPLICATIONS

The findings from the study confirm the general perception that SMEs tend to focus much attention on the customer end of the business than the supplier side. The study has revealed that although SMEs acknowledge the impact of supply management on their operations, the general lack of supply management thinking has meant that the potential contribution from the supply side of business is left unexploited. If SMEs with a human resource deficit in supply management are offered support in the form of training and awareness to enhance their supply management capabilities, they will be able to harness the huge potential in the supply side of their business to increase their efficiency and, ultimately, their profitability.

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# **ASSESSING THE IMPACT OF MARKETING/SUPPLY CHAIN INTEGRATION ON BUSINESS PERFORMANCE USING A MEASUREMENT TAXONOMY**

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## **INTRODUCTION**

It has been repeatedly suggested in conceptual and empirical research on the concept of market orientation that inter-functional and cross-organisational coordination is the key to achieving the main goal of marketing, the creation of superior customer value (Jaworski and Kohli, 1993, Juettner *et al.*, 2010, Haddad and Ren, 2013). Thus, relationship between different disciplines sharing the same customer focus has emphasized the importance of integration between the demand side managed by marketers and the supply side managed by the supply chain department (Esper *et al.*, 2010). A major obstacle, to inter-functional and procedural cooperation/integration, is conflicting key performance indicators (KPIs) between marketing and supply chain management (SCM) (Juettner *et al.*, 2007).

Research within both disciplines emphasizes the mutual benefits of the proposed integration. However, evidence has been revealed that integration throughout the supply chain (SC) is an objective of the conceptual theory yet not realized in practice (Mentzer and Gundluch, 2010). The main reason might be failure to identify and assign specific measures to assess the SC performance on an intra- and inter-organisational level. Although marketing/SCM integration was strongly supported in scholarly work, very little empirical research has been done to identify measurements to assess the impact of this integration (Juettner *et al.*, 2007, Esper *et al.*, 2010; Haddad *et al.*, 2012).

The purpose of this paper is to identify the main marketing capabilities that might influence the five major SC attributes (reliability, flexibility, responsiveness, cost and asset management) (Supply-Chain Council, 2008) and define the strength of the proposed influence. Secondly, the research explores marketing and SC performance measures that might assess the impact of functional and procedural integration between the marketing domain and the SC domain based on a literature content analysis, Supply Chain Operations Reference (SCOR) model and empirical study related to industry's best practices.

The structure of this paper is organized as follows: first, an analytical literature review on the integration between marketing and SCM is presented. Then, an inductive methodological approach is followed to identify the major marketing capabilities influencing SC performance

and to explore specific marketing/SCM measures for assessing the proposed marketing capabilities impact on the five different SC attributes. Hence, a refined structured marketing/SCM taxonomy of performance measurements is proposed. Finally, the conclusion is outlined.

## **LITERATURE REVIEW**

In the existing highly competitive markets, possessing clear customers' insights and responding effectively to their different needs, through the coordination and integration of marketing and SCM, can be a source of a superior competitive advantage. This literature review aims at facilitating the understanding of the levels of integration between marketing and SCM, namely inter-functional perspective, a process perspective (cross-organisational) and the perspective of integrating business concepts. Moreover, it discusses the lack of integrative measures capable of evaluating the impact of this integration.

A series of papers, discussing the integration of marketing and supply chain, were reviewed (e.g. Lambert and Cooper, 2000; Alvarado and Kotzab, 2001; Flint, 2004; Juettner *et al.*, 2007; Juettner *et al.*, 2010; Mentzer and Gundlach, 2010; Knoppen *et al.*, 2010) to fully realise the development stages of the integration views. A recent research paper (Juettner *et al.*, 2010) classified the current research carried out on the integration into three perspectives, namely, an inter-functional perspective, a process perspective and the perspective of integrating business concepts.

First, the inter-functional perspective mainly refers to the close connection between logistics and marketing. SCM has evolved from the logistics concept and logistics was originated as the physical side of distribution, which is a main pillar of the marketing concept. Second, the process perspective mainly incorporates the cross-organizational collaboration and coordination aspect, between all SC partners, that is designed to create value throughout the supply chain. Third, although not necessarily always referred to as a part of marketing/SCM link, integrated business concepts such as quick response, agile SCM and demand chain management, are the most recent trends concerning the integration between marketing and SCM. The integrated business concepts are built to establish solid competitive advantages enhancing performance of supply chain against competing chains (Juettner *et al.*, 2010).

Developing on the current body of knowledge, it is obvious that the interface between marketing and SCM, on an inter-functional level or cross-organisational or on the three integration perspectives (Juettner *et al.*, 2010), is mainly concerned with market or customer orientation, in terms of building and sustaining customer relationships, creating value and customer satisfaction. The marketing's domain and strength remain in understanding customers' perceived value (obtaining market and customer knowledge), dividing customer with similar needs and wants into distinct groups (market/customer segmentation), transforming these needs and wants into product and service packages to meeting the different desires (targeted marketing mixes) and marketing channels design (Juettner *et al.*, 2007; Kotler and Armstrong, 2010; Haddad and Ren, 2013). These are the demand-focused activities owned by the marketing side.

The part that remains under-researched is the impact of these marketing activities on the five major SC attributes (reliability, flexibility, responsiveness, cost and asset management). Unfortunately, very few measures have been assigned in the literature to assess the impact of the marketing/SCM integration on performance (Shepard and Guenter, 2006; Gunasekaran *et al.* 2007; Haddad and Ren, 2012). Moreover, a scant attention has been



given to the dilemma on decision making methods in relation to which performance measures to be adopted (Neely, 2005).

Marketing and SCM integration is a process of demand creation and fulfilment. Hence, as argued by Haddad and Ren (2013) customer value creation and improved business performance cannot be achieved unless efforts are integrated from the demand side (marketing) and supply side (SCM). They presented partial evidence of the positive impact of the successful Demand/Supply integration on business integrative rather than functional KPIs. According to Juettner *et al.* (2007) the functional KPIs appear to be a major barrier to collective integration goals. He argued based on his empirical study functional KPIs prohibits tactical managers from aiming at the overall company goals and narrow their efforts towards functional goals. As an alternative, integrative KPIs are designed to cover a broader set of collective company objectives rather than assessing functions on isolated or conflicting performance measures. These literature review findings assisted the researcher in choosing an appropriate research approach to select and assign integrative KPIs evaluating the impact of the integration between marketing and supply chain.

### **RESEARCH METHODOLOGY**

As highlighted before, this area of integration is understudied in research. This research is exploratory in nature and requires qualitative methods to identify the relevant constructs and develop the required measurement taxonomy. An inductive reasoning approach is followed as this research is mainly based on qualitative analysis methods. Hence, the researchers will be able to generate substantive understanding and knowledge about this new concept (Kotzab, 2000).

This research is a part of an on-going work where an initial conceptual framework was proposed (Haddad *et al.*, 2012). This framework suggests that marketing capabilities influence supply chain performance attributes might be measured by market and customer oriented SCP measurements developed based on a literature content analysis. The first phase of this inductive study is to conduct semi-structured interviews, with strategic and tactical managers from five Fast Moving Consumer Goods (FMCG) industry best practices including Proctor and Gamble and Unilever as shown in table 1, to validate the literature content analysis proposed measures (Haddad *et al.*, 2012) and to further explore new measures reflecting and assessing marketing/SCM integration levels. Moreover, this part also aims at highlighting the main marketing capabilities influencing the SC main attributes.

<b>Company</b>	<b>Global coverage and scale</b>	<b>Industry and Egyptian market shares 2012</b>	<b>The Gartner Supply Chain Top 25 for 2012 (Global and Europe)</b>
Unilever Mashreq	Multinational operating in 148 countries, brands are being sold in 180 countries	Holds 46.3% of the Egyptian home and personal care, tea and bouillon market value	Global ranking: 10th place in the top 25 rankings and 3rd FMCG Europe: 1st place

Proctor and Gamble Egypt	Multinational operating in around 75 countries, brands are being sold in 180 countries	Holds 7.5% of the Egyptian Hair care and deodorant market value	Global ranking: 3rd place in the top 25 rankings and 1st FMCG  Not on the European list.
Soft drinks company	Multinational company operating and brands being sold in around 200 countries	Holds more than 30% of the Egyptian soft drinks' market value	Listed in the top 15 ranks of Gartner  Not on the European list.
Sweet and savory snacks company	Multinational company operating and brands being sold in around 200 countries	Holds more than 50% of the Egyptian sweet and savory snacks value	Listed in the top 15 ranks of Gartner  Not on the European list.
Sweet snacks company (Chocolate Confectionery and ice cream)	Multinational company operating in around 73 countries	Holds more than 20% of the Egyptian Chocolate Confectionery and ice cream market values	Not listed on the Gartner Supply Chain Top 25 for 2012

Table1: FMCGs' companies covered in this study

Source: (Euromonitor Passport report, 2012; Retail audit report, 2012; Gartner Supply Chain Top 25, 2012; Unilever company records; P&G company records).

Given the nature of this phase the interviews were of the semi-structure format. The intention was to explore and gain more insights into the process implementation. Throughout the interviews more aspects of the integration process were uncovered. This ongoing expansion and improvement of the interview protocol is a part of the process of grounded theory development (Glaser and Strauss, 1967).

During the second phase, a structured approach was followed to and to illustrate the weighted impact of the different proposed marketing capabilities to the five major SC attributes. Moreover, the structured interview also resulted in the design the marketing/SC measurement taxonomy building on previous research work (Shepard and Guenter, 2006; Haddad et al., 2012; Haddad and Ren, 2013). This was realised through structured 120 to 180 minutes interviews with strategic and tactical managers from the same five FMCGs global leading companies. During the structured interviews, the refined semi-structured interviews' results accompanied by a few added SCOR model measurements were presented

to the managers at these companies. They were supposed to decide on a five to one scale (strongly agree to disagree) whether they consider the proposed measurements relevant to assess the impact on each marketing capability on the five SC attributes.

## **RESULTS AND ANALYSIS**

The first phase of the study resulted in nine main marketing capabilities that are, from the interviewees perspective, capable of influencing the five SC performance measurement attributes. As shown in Table 2 these capabilities are namely, Segmentation, Market Forecasts and Planning, Automated Applications, Customer Knowledge Building, Targeted Marketing Mixes, Managing Marketing Channels, Customer Involvement Programs, Customer Relationship Building and Selling Activities.

As for the second phase, these capabilities were tested against the five SC measurement attributes on a five to one scale (as explained in the previous part) where marketing forecasting and planning scored the highest weighted average versus the other capabilities. In addition, SC responsiveness appears to be the most SC measurement influenced by the marketing capabilities.

Furthermore, after analysing the results of semi-structured interviews regarding measures the content analysis, the SCOR model was used to add more strategic and tactical measures. As a result a set of measurements were assigned to each SC attribute (reliability, flexibility, responsiveness and asset management) were tested against each marketing capability resulting from the previous phase. Different measures appeared to be able to assess the impact of each marketing capability on each of SC performance attributes, composing a taxonomy of measurements capable of evaluating the marketing/SCM integration as shown in table 3. The KPIs presented in table 3 are the KPIs that scored over 4

<b>SC attributes/ marketing capabilities</b>	<b>Segmentation</b>	<b>Market forecasts and planning</b>	<b>Automated applications</b>	<b>Customer knowledge building</b>	<b>Targeted marketing mixes</b>	<b>Managing marketing channels</b>	<b>Customer involvement programs</b>	<b>Customer relationship building</b>	<b>Selling activities</b>	<b>Total weighted average for each SC attribute</b>
SC reliability	4.82	5	3.55	4.3	4.64	4.82	4.27	4.27	4.45	40.10
SC flexibility	4.45	5	3.55	4.1	4.64	4.36	4.64	4.27	4.64	39.64
SC cost	4.09	4.8	3.36	3.7	4.09	4.64	3.91	3.91	4.27	36.80
SC Responsiveness	4.82	5	3.91	4.3	4.55	4.64	4.64	4.45	4.45	40.73
SC asset management	4.27	5	3	3.5	3.55	4.45	4.09	3.73	3.91	35.54
total weighted average marketing capability	22.45	24.80	17.37	19.91	21.45	22.91	21.55	20.64	21.73	

Table 2: Marketing capabilities weighted impact on SC performance attributes

<b>SC attributes / marketing capabilities</b>	<b>Segmentation</b>	<b>Market forecasts and planning</b>	<b>Automated applications</b>	<b>Customer knowledge building</b>	<b>Targeted marketing mixes</b>	<b>Managing marketing channels</b>	<b>Customer involvement programs</b>	<b>Customer relationship building</b>	<b>Selling activities</b>
SC reliability	<b>P</b> Perfect Order Fulfilment <b>L</b> Level of customer perceived value <b>S</b> Sales turnover	<b>P</b> Perfect Order Fulfilment <b>F</b> Forecast accuracy <b>C</b> Customer satisfaction	<b>P</b> Perfect Order Fulfilment <b>F</b> Forecast accuracy	<b>P</b> Perfect Order Fulfilment <b>F</b> Forecast accuracy	<b>P</b> Perfect Order Fulfilment <b>R</b> Range of products and services <b>S</b> Sales turnover	<b>P</b> Perfect Order Fulfilment <b>L</b> Level of customer perceived value <b>C</b> Customer satisfaction	<b>P</b> Perfect Order Fulfilment <b>F</b> Forecast accuracy <b>A</b> Annual Rate customers retained	<b>P</b> Perfect Order Fulfilment <b>S</b> Sales turnover <b>C</b> Customer life time value	<b>P</b> Perfect Order Fulfilment <b>F</b> Forecast accuracy <b>S</b> Sales turnover
SC flexibility	<b>C</b> Customer satisfaction <b>U</b> Upside Supply Chain Adaptability	<b>U</b> Upside Supply Chain Flexibility <b>U</b> Upside Supply Chain Adaptability <b>L</b> Level of Information sharing	<b>U</b> Upside Supply Chain Adaptability <b>D</b> Downside Supply Chain Adaptability <b>L</b> Level of Information sharing	<b>L</b> Level of customer perceived value <b>B</b> Buyer-supplier partnership level <b>L</b> Level of Information sharing	<b>U</b> Upside Supply Chain Flexibility <b>U</b> Upside Supply Chain Adaptability <b>L</b> Level of customer perceived value	<b>U</b> Upside Deliver Adaptability <b>D</b> Downside Deliver Adaptability <b>U</b> Upside Deliver Flexibility	<b>U</b> Upside Deliver Adaptability <b>U</b> Upside Deliver Flexibility <b>A</b> Annual Rate customers retained	<b>L</b> Level of customer perceived value <b>B</b> Buyer-supplier partnership level <b>L</b> Level of Information sharing	<b>U</b> Upside Deliver Adaptability <b>U</b> Upside Deliver Flexibility <b>C</b> Customer satisfaction
SC Responsiveness	<b>O</b> Order Fulfilment Cycle	<b>O</b> Order Fulfilment	<b>O</b> Order Fulfilment	<b>R</b> Responsiveness to urgent	<b>P</b> Plan Cycle Time	<b>O</b> Order Fulfilment	<b>O</b> Order Fulfilment	<b>O</b> Order Fulfilment Cycle Time	<b>O</b> Order Fulfilment

iveness	Time <b>R</b> esponsiveness to urgent deliveries <b>C</b> ustomer satisfaction	Cycle Time <b>P</b> lan Cycle Time <b>S</b> ales turnover	deliveries <b>L</b> evel of Information sharing	Customer satisfaction <b>S</b> ales turnover	Cycle Time <b>D</b> eliver Cycle Time <b>R</b> esponsiveness to urgent deliveries	Cycle Time <b>D</b> eliver Cycle Time <b>C</b> ustomer satisfaction	Level of Information sharing <b>C</b> ustomer life time value	Deliver Cycle Time <b>S</b> ales turnover
SC cost	<b>S</b> upply Chain Management Cost <b>C</b> ost to Deliver	<b>S</b> upply Chain Management Cost <b>C</b> ost to Plan Supply Chain	<b>S</b> upply Chain Management Cost <b>C</b> ost to Deliver	<b>S</b> upply Chain Management Cost <b>C</b> ost to Plan Supply Chain <b>C</b> ost to Deliver	<b>S</b> upply Chain Management Cost <b>C</b> ost to Deliver <b>O</b> rders Management Costs	<b>S</b> upply Chain Management Cost <b>C</b> ost to Deliver <b>B</b> uyer-supplier partnership level	<b>S</b> upply Chain Management Cost <b>C</b> ost to Deliver	<b>C</b> ost to Deliver <b>O</b> rders Management Costs
SC asset management	<b>R</b> eturn on Working Capital <b>C</b> ash-to-Cash Cycle Time	<b>R</b> eturn on Working Capital <b>C</b> ash-to-Cash Cycle Time	Non over 4	<b>F</b> inished Goods Inventory days of supply <b>A</b> nnual Rate customers retained	<b>R</b> eturn on Working Capital <b>C</b> ash-to-Cash Cycle Time	<b>R</b> eturn on Working Capital <b>R</b> eturn on Supply Chain Fixed Assets <b>C</b> ustomer life time value	<b>R</b> eturn on Working Capital <b>R</b> eturn on Supply Chain Fixed Assets <b>C</b> ustomer life time value	<b>R</b> eturn on Working Capital <b>C</b> ash-to-Cash Cycle Time

Table 3: A marketing/SCM integration measurement taxonomy

for a weighted average in sequence (max. 3 KPIs are presented for each intersection). The KPIs that were consistently reappearing with the different marketing capabilities are Perfect Order Fulfilment, Forecast Accuracy and Customer Satisfaction with the SC attribute reliability. In addition, Upside SC Flexibility, Upside SC Adaptability and Level of information Sharing appeared often with SC flexibility. As for SC responsiveness, it was strongly related to Order Fulfilment Cycle Time and Responsiveness to Urgent Deliveries and Sales Turnover, while SC cost appears to be mainly aligned with SC Management Cost to assess the different marketing capabilities impact. Finally SC asset management was believed to be the SC attribute at is impacted the least by the marketing capabilities. It is mainly suggested to be assessed by Return on Working Capital and Cash-to-Cash Cycle Time.

**Partial evidence of positive impact of the integration on main KPIs resulting from the research:**

The following part presents some evidence that the successful and comprehensive implementation of the marketing and SC integration model can render positive results on business performance. The case study participant interviewees considered the integration main contributor to the continuous improvement in the KPIs resulting from the study like forecasting accuracy and in other integrative KPIs (e.g. Perfect order fulfilment, sales turnover etc.). The organisation that granted access to its KPIs was Unilever Mahshreq (Figure 3).

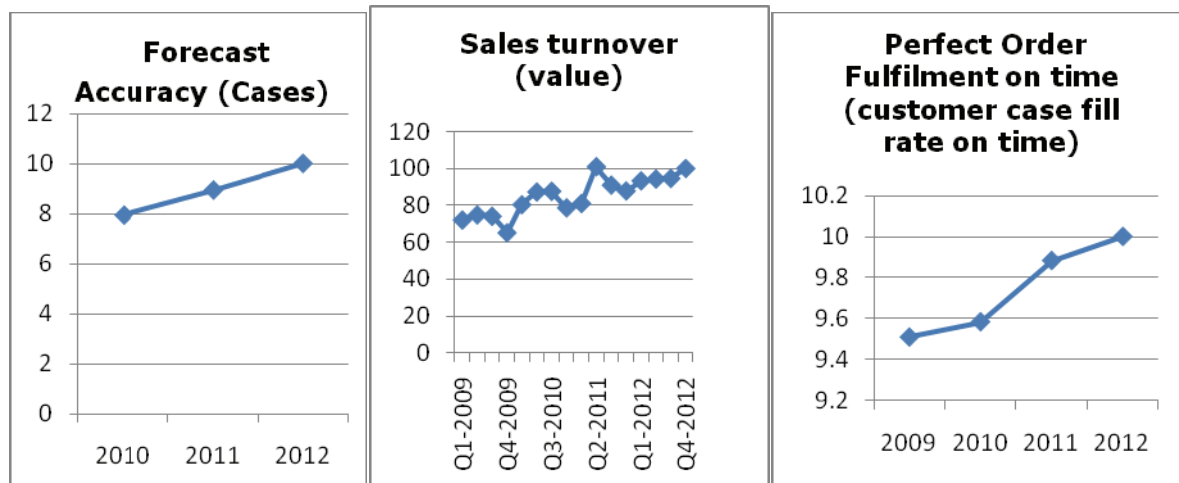


Figure 3: Integrative KPIs of Unilever Mashreq

(Source: Unilever Mashreq company records, 2012)

**CONCLUSION**

A major academic/practical gap has been identified based on literature studies on the integration of SCM and marketing functions and measurements. Other parts of this ongoing research proposed a conceptual framework on integration between marketing and SCM. This framework is supported by the taxonomy of marketing/SCM measurements, presented in this paper, which is validated based four FMCG industry global leading companies. The study reveals that the KPIs of these best practices are might be positively influenced by these integration practices.

Marketing and SCM scholars and researchers have to unify their efforts to generate a clear understanding of SCM and marketing as interrelated disciplines that cannot be

separated, especially following the recent SC customer focus views. The marketing side creates value and SCM delivers it, thus, this assumption should constantly be measured for validity using integrative measurements. Hence, this study directs marketing and SC managers to some integrative KPIs to justify the positive relationship on the overall performance.

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# SUPPLIER DEVELOPMENT AS AN ALTERNATIVE INVESTMENT IN SUPPLY CHAINS UNDER FINANCIAL REPRESSION

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## 1. INTRODUCTION

In recent years, central banks have flooded the financial markets with liquidity to overcome economy crises and to reanimate global growth. The European Central Bank, for instance, has propped up the European financial system with over € 1 trillion of cheap loans to support banks and to reduce pressure on government borrowing rates. Despite these measures, there is still a liquidity bottleneck, especially for small and medium-sized companies that depend disproportionately on bank loans. These companies are currently suffering under a credit crunch that increases their operating expenses and curbs necessary investments (Ball and Brat 2013). While policy makers are still discussing options to circumvent this problem, industrial companies have already implemented practical solutions. Large companies with better access to capital that, in part, face the opposite problem and hoard liquidity due to low deposit rates, began to support their suppliers by providing information to investors or by financing investments themselves (Randall and Farris, 2009). The presented example illustrates, besides coordinating operations, the idea of an integrated view of the supply chain with regard to upstream and downstream flows of products, information and financial resources has become increasingly important in recent years (cf. Mentzer et al. 2001). The significant impact collaborative financial supply chain management may have led to an optimization of supply chain cash flows. This helps to generate direct earnings that increase company values and enhance the competitiveness of the supply chain as a whole (Randall and Farris, 2009). The objectives of financial supply chain management are: (I) to utilize capital in an efficient manner when investing in assets taking into account access to cash by, and capital requirements of, players in the chain, and (II) to reduce working capital by ensuring efficient processes throughout the supply chain.

These two aspects of financial supply chain management will be considered in this paper, which studies integrated inventory and financing decisions in a two-stage supply chain. It is assumed that a large and established company supports its small but strategically important supplier that suffers under a credit gap. The support is provided by investing in the supplier's improvement programs, which raises production capacity to cope with increased demand volume or results in higher product quality to meet customer expectations. For this purpose, a mathematical model of a single-supplier-single-buyer supply chain is developed. The supplier can invest in improved production technology by either increasing the production rate or reducing the fraction of defective items produced in a lot. As small suppliers are usually very limited in financing expensive investments due to relatively high interest rates on loans, an alternative financing arrangement is considered. To encourage investments, the buyer grants its supplier a loan from its cash holdings or extends its credit facilities. As the buyer is assumed to have better access to loans with better rates than the supplier, both companies are expected to benefit from such an agreement (see Randall and Farris, 2009). Since the supplier is better in

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acquiring loans with lower interest rates, he/she is then more likely to consider investing in projects that improve the system's productivity. Simultaneously, the buyer benefits from the investment by realizing a better interest yield on its sales revenues, by reducing the risk of a supplier becoming unavailable, by ensuring consistently low procurement prices, and by securing access to technologically advanced high quality products. Compared to classical trade finance approaches such as supplier credits, we consider internal and external investment opportunities that lead to a better utilization of the available capital. Thus, this paper is one of the first to study lot sizing and financial investment decisions in a supply chain context. Besides, different investment opportunities along the supply chain are considered that may lead to improvements for the companies under consideration and for the network as a whole. Additionally, it is shown that both members of the supply chain may benefit from using the suggested approach of internal financing and supplier development.

The remainder of the paper is organized as follows: Section 2 provides a review of the relevant literature on productivity improvement and supplier development investments in inventory models. Section 3 introduces the notations and assumptions and develops mathematical models for inventory planning with supplier development investments. Section 4 provides some numerical examples to illustrate the provided models. Finally, Section 5 concludes the article and suggests some directions for future research.

## **2. LITERATURE REVIEW**

The literature on inventory management suggests different approaches for process improvement investments in production processes. Such investments usually aim at exploiting possible improvements of various processes in a company; e.g., making new technologies available, utilizing synergies, or creating additional capacity to increase productivity. The focus of the literature has been on two types of process improvement investments: (I) investments in improving process quality by reducing the number of defective items that are generated during production and (II) investments in increasing the production speed.

One of the first papers treating process improvement investments in the context of production and inventory planning was the one by Porteus (1986). He developed an order quantity model where setup costs and process quality were assumed variable and dependent on investment. Three different investment options were investigated, and it was shown that simultaneous investments in process quality and setup cost reduction lead to lower total cost. Keller and Noori (1988) analyzed a continuous review reorder point order quantity model with quality improvement investments for two demand distributions (uniformly and exponentially) during lead time. Hong and Hayya (1995) extended the work of Porteus (1986) by providing a solution procedure considering a budget constraint for investments. It was shown that under limited financial resources, it is beneficial to invest either in quality or setup cost reduction if the investment is below a threshold level. Only if the level is exceeded, joint investments should be made. Moreover, Ouyang and Chang (2000) and Ouyang et al. (2002) investigated process quality improvement investments in a continuous review lot size reorder point model

with partial backordering and variable lead times. By comparing normally distributed demand with distribution-free demand, the authors showed that investments in process quality are beneficial, especially in the case where information on demand is limited. Affisco et al. (2002), in contrast, considered investing to improve quality and to reduce setup costs in an integrated inventory setting, and determined the optimal lot size and investment amount from a system perspective. It was shown that in the quality-adjusted integrated inventory model, investments lead to significant cost reductions which are, caused by synergistic effects, the highest in the simultaneous quality and setup improvement case. Another supplier-buyer integrated inventory model that also considered quality improvement investments was proposed by Yang and Pan (2004). They simultaneously optimized order quantity, lead time, process quality and the number of deliveries under normally distributed lead time demand. It was shown that several benefits, such as lower cost, higher quality, smaller lot-sizes and shorter lead-time can be achieved. In addition, Comeaux and Sarker (2005) relaxed several assumptions of some earlier works by introducing a partial quality inspection process and by considering non-repairable defective products as well. Further treatment of quality improvement investments in an integrated inventory setting can also be found in Liu and Centinkaya (2007), Ouyang et al. (2007) or Parveen and Rao (2009), among others.

A second stream of research, which is relevant to this paper, assumes that the production rate of a facility is variable and may be influenced by varying the performance of the production system or by changing idle times. One of the first papers that dealt with variable production rates is the one of Buzacott and Ozkarahan (1983), who considered a scheduling problem of two products on a single or two machines when demand is constant and there is changeover cost. They showed that for all cases considered, it is optimal to choose production rates in such a way that machines are always fully utilized. An extension to this model was proposed by Silver (1990), who considered a family of items produced in a common cycle on a single facility. The production rate was assumed variable between prescribed limits and it was shown that avoiding idle time in general is not optimal. Eiamkanchanalai and Banerjee (1999) developed an approach for determining the optimal run time and production rate for a single item. To capture the effect of deviations from the designed system output rate, production costs per unit were assumed to be a quadratic function of the production rate. More recently, Glock (2010, 2011) studied the impact of variable production rates on the inventory build-up and the total cost of two- and multi-stage production systems. He showed that considering variable production rates in a production system is an appropriate measure to reduce excessive system inventory.

Although several works on process improvement investments exist in the inventory management literature, a combination of different investment alternatives for increased productivity under different financial environments has not been investigated so far. Moreover, all inventory models that consider more than a single stage only considered a system perspective, which is why the option to share necessary investments and the resulting financial benefits have not been studied thus far. Even though, few researchers have discussed strategic implications of sharing investments between suppliers with limited financial resources and large customers in supply chains in the context of supplier development. Cohen and Agrawal (1999) as well as Talluri and Lee (2010) investigated

the value of supplier development investments in long-term relationships and their effect on performance and purchase prices. More recently, Friedl and Wagner (2012) compared the two strategic options of supplier switching and supplier development and showed that in many cases, supplier development investments should be preferred to changing suppliers. For this reason, different investment opportunities for increased productivity will be studied in a two-staged supply chain by considering different financing alternatives hereafter.

### 3. MODEL DEVELOPMENT

The scenario described above is examined in the following model that studies integrated inventory and financing decisions in a two-stage supply chains. A large and well-established buyer sources some strategically important components from a rather small supplier (note that this is quite common in certain industries such as automotive or retailing sector). To cope with increased customer demand, the supplier can invest in improved production technology by either increasing the production speed or by reducing the amount of defective items produced per production run. As small suppliers are usually very limited in financing expensive investments due to relatively high interest rates for loans (cf. Ball and Brat, 2013), an alternative financing arrangement is considered. Instead of depositing sales revenues in an interest bearing account, the buyer may give a credit to its supplier to encourage investments. The buyer is assumed to have a significantly better position in terms of liquidity and solvency, which is why he can provide better access to loans for the supplier. The entire supply chain benefits from this cooperation extended to financial flows, as the overall investment strategy is improved by taking advantage of better capital allocation. This results in significant cost savings. The supplier receives a cheaper loan and is able to invest to improve productivity. The buyer, on the other hand, may realize a better interest yield on its sales revenues and reduces the risk of a supplier breakdown.

Apart from the assumptions already mentioned, we assume the following hereafter:

1. The inventory system involves a single item and has an infinite planning horizon.
2. Shortages are not allowed as the lead time and the demand rate  $D$  for the item are assumed to be deterministic and constant over time.
3. The production rate can be varied between given limits  $P_{min}$  and  $P_{max}$ . The case of synchronized production, where the supplier constantly produces without setups, is excluded by assuming that  $P_{min} > D$ .
4. The production rate of the supplier may be influenced by investments. The relationship between capital investment  $a_P(P)$  and the actual production rate  $P$  follows the logarithmic function  $a_P(P) = \delta_P \ln\left(\frac{P}{P_{min}}\right)$  for  $P_{min} < P < P_{max}$ , where  $P_{min}$  denotes the production rate in case no investment is made.  $\frac{1}{\delta_P}$  is the percentage increase in  $P$  per euro increase in investment  $a_P(P)$ .
5. The production process is assumed to be in control at the beginning of each production cycle. While producing a lot, the process can go out of control with probability  $\gamma$ . Once out of control, the process only generates defective items until the entire lot is finished and a new setup is conducted.
6. The quality level may be influenced by investments. The relationship between capital investment  $a_\gamma(\gamma)$  and the process quality level  $\gamma$  follows the logarithmic

function  $a_Y(\gamma) = \delta_Q \ln(\gamma_0/\gamma)$  for  $0 < \gamma < \gamma_0$ , where  $\gamma_0$  denotes the process quality in case no investment is made.  $\frac{1}{\delta_Q}$  is the percentage decrease in  $\gamma$  per euro increase in investment  $a_Y(\gamma)$ .

In addition, the following terminology is used:

$A$  = ordering costs per order for the buyer

$C_V$  = unit production cost incurred by the supplier

$C_B$  = unit purchase cost incurred by the buyer

$C_M$  = unit replacement cost per defective item for the supplier

$C_N$  = unit inspection cost for the buyer

$D$  = demand rate in units per unit time

$\gamma$  = fraction of non-conforming items

$i_B$  = lending rate for the buyer

$i_C$  = contracted interest rate between supplier and buyer

$i_V$  = lending rate for the supplier

$P$  = production rate in units per unit time

$Q$  = order quantity of the buyer

$r$  = annual inventory carrying charge per dollar

$S$  = setup and transportation costs for the supplier

### Scenario 1: Individual decisions without financing agreement

Considering a basic two-stage inventory setting, a single manufacturer produces to order for a single buyer under deterministic conditions. The buyer uses a common EOQ-type inventory control policy and periodically orders batches of identical sizes that are shipped on a lot-for-lot basis. As stated above, the production process can go out of control during each production run. In an out-of-control state, the process generates defective items until the batch has been completed. Accordingly, the supplier incurs an extra cost for rework and handling of these defective items. Considering that the production rate and process quality can be improved at an investment, the corresponding investment costs have to be included. As a result, taking into account setup, inventory holding, rework and investment financing cost, the total cost per unit of time for the supplier amount to:

$$TC_V(P, \gamma) = \frac{SD}{\gamma Q} + \frac{Q}{2\gamma r} \frac{D}{P} C_V + \frac{D}{\gamma} (1 - \gamma) C_M + i_V [a_P(P) + a_Y(\gamma)] \quad (1)$$

where  $\bar{\gamma} = 1 - \gamma$  is the fraction of acceptable items produced in the process.

As the production process generates a constant fraction of defective items, the buyer conducts a 100% inspection policy that is assumed to be error-free. All items detected during inspection will be replaced by the supplier at an additional expense. Hence, the total costs per unit of time for the buyer contain ordering and inventory holding as well as inspection cost, which leads to:

$$TC_B(Q) = \frac{AD}{\bar{\gamma}Q} + \frac{Q}{2}\bar{\gamma}rC_B + \frac{DC_N}{\bar{\gamma}} \quad (2)$$

### Scenario 2: Individual decisions with financing agreement

In contrast to scenario 1, it is now assumed that the buyer may reach a contractual agreement with the supplier to invest in process improvements that increase the supplier's production rate and/or reduce the fraction of defective items that are generated during production. Therefore, the supplier's credit rate reduces to the agreed level, which is necessarily in-between the two independent borrowing rates. Thus, the total costs per unit of time for the supplier have to be adjusted to:

$$TC_V(P, \bar{\gamma}) = \frac{SD}{\bar{\gamma}Q} + \frac{Q}{2}\bar{\gamma}r\frac{D}{P}C_V + \frac{D}{\bar{\gamma}}(1 - \bar{\gamma})C_M + i_c[a_P(P) + a_Y(\bar{\gamma})] \quad (3)$$

As the buyer has better access to credit from financial institutions than the supplier, he/she is able to realize profit from interest as long as the interest rate he/she receives is smaller than the credit conditions he/she offers to his/her supplier. Thus, the total costs per unit of time are now given as:

$$TC_B(Q) = \frac{AD}{\bar{\gamma}Q} + \frac{Q}{2}\bar{\gamma}rC_B + \frac{C_N D}{\bar{\gamma}} - (i_c - i_B)[a_P(P) + a_Y(\bar{\gamma})] \quad (4)$$

### Scenario 3: Integrated decision with financing agreement

Assuming that both parties cooperate by determining a jointly optimal inventory policy and investment structure, the joint total relevant cost per unit of time for the supplier and the buyer are given as:

$$TC_s(Q, P, \bar{V}) = \frac{(S+A)D}{\bar{V}Q} + \frac{Q}{2}\bar{V}r\left(\frac{D}{P}C_V + C_B\right) + \frac{D}{\bar{V}}((1-\bar{V})C_M + C_N) + i_B[a_P(P) + a_V(\bar{V})] \quad (5)$$

When searching for the optimum values of the decision variables in the individual decision cases, it has to be considered that the order quantity is determined by the buyer, whereas the production rate and quality level are set by the supplier. As the individual decision variables are intertwined, a solution to this problem can be found by assuming a Stackelberg equilibrium in which the supplier acts as the leader by determining its productivity and the buyer as the follower by setting its order quantity. Thus, the supplier will anticipate the buyer's order quantity while deciding on its productivity. Differentiating the buyer's cost function with respect to its decision variable  $Q$  leads to its response function to every quality level decision of the supplier:

$Q^* = \frac{1}{\bar{V}}\sqrt{\frac{2AD}{rC_B}}$ . Thus, anticipating this relation, the supplier is able to make its decision on production rate and the quality level that minimizes its cost (Note that it can be shown that the supplier's total cost function is convex in  $\bar{V}$  and  $P$ ). The optimal policy for the integrated case may be derived by setting the partial derivatives equal to zero and solving the resulting system of equations (see Affisco et al., 2002, among others). The total costs for the supplier and the buyer may then be derived by inserting the optimal values in the cost functions (3) and (4) while considering the particular interest rate that the supplier and the buyer negotiated for the agreement.

#### 4. NUMERICAL ANALYSIS

Before analysing the effects of different interest agreements on the production structure and the total cost in detail, the following example illustrates the behaviour of the models developed in this paper. Consider a supplier-buyer relationship with the following parameters:  $A = \text{€}100/\text{order}$ ,  $C_V = \text{€}20/\text{unit}$ ,  $C_B = \text{€}25/\text{unit}$ ,  $C_M = \text{€}12/\text{unit}$ ,  $C_N = \text{€}5/\text{unit}$ ,  $\frac{1}{\delta_P} = 0.00075$ ,  $\frac{1}{\delta_Q} = 0.00005$ ,  $D = 1000$  units/year,  $\bar{V}_0 = 0.80$ ,  $i_B = 0.06$ ,  $i_C = 0.10$ ,  $i_V = 0.14$ ,  $P_{\min} = 2000$  units/year,  $P_{\max} = 6000$  units/year,  $r = 0.20$ ,  $S = \text{€}400/\text{setup}$ . Applying the proposed solution procedures leads to the following inventory and investment decisions for the considered scenarios:

	Individual decisions without agreement	Individual decisions with financing agreement	Individual decisions with financing agreement	Integrated decisions with financing agreement
$Q$ (units)	239.04	229.10		447.90
$P$ (units)	2143	3000		6000
$\bar{V}$ (%)	0.8367	0.8730		0.9379
$a(P)$ (€)	91.99	540.62		1464.82

$\pi^c$ (€)	4050.28	9079.93	23393.36
$TC_V$ (€)	5109.24	4841.36	4372.49
$\Delta TC_V$ (%)	-	-5.24%	-9.68%
$TC_B$ (€)	6976.11	6342.66	5624.96
$\Delta TC_B$ (%)	-	-9.08%	-11.32%
$TC_S$ (€)	12085.35	11184.02	9997.45
$\Delta TC_S$ (%)	-	-7.46%	-10.61%

Table 1: Comparative results

As can be seen in Table 1, replacing expensive bank loans by a financing agreement between the supplier and the buyer leads to significant cost reductions for both players. Furthermore, as investments in production rate and quality level increase, the supplier's productivity improves. In the given setting, further cost reductions can be realized by integrating planning and applying a joint lot-sizing policy, which also leads to increased productivity investments. Nevertheless, approximately 43% of the possible cost savings and 26% of the efficient investments are realized under the given interest agreement.

Considering that the agreed interest rate  $i_c$  is not necessarily fixed, but will be in-between the two individual lending rates depending on the bargaining power of the two players, the effects of a variation of  $i_c$  have to be investigated in more detail. As can be expected, higher interest rates for the financing arrangement increase the supplier's total cost. From the buyer's point of view, by contrast, an optimal interest rate exists that minimizes its total cost (cf. Figure 1a)). The optimal interest rate obviously balances revenues from interests and benefits that result from process improvements at the supplier. In the assumed setting, it is reasonable that the buyer will deploy its bargaining power to establish the individually optimal interest rate, which limits overall investments.

As the total cost are fixed in the integrated decision scenario, varying interest rates merely affects the allocation of the cooperation gains (cf. Figure 1b)). As the buyer always benefits from the considered agreement, its reservation level will always be satisfied. The supplier, in contrast, reaches its reservation level at an interest rate of approximately 13% in the present example. If the reservation level is reached, the supplier is no longer interested in participating in the cooperation. Further increases in the interest rate consequently have to be compensated by the buyer, which restricts its fraction of the cooperation gain in the integrated setting.



As to production conditions, a reduction in interest rates leads to a disproportionate increase in productivity (cf. Figure 1c)). In addition, the productivity gap between the decentralized solution without financing agreement and integrated planning under different interest conditions can almost completely be closed by the proposed investment arrangement.

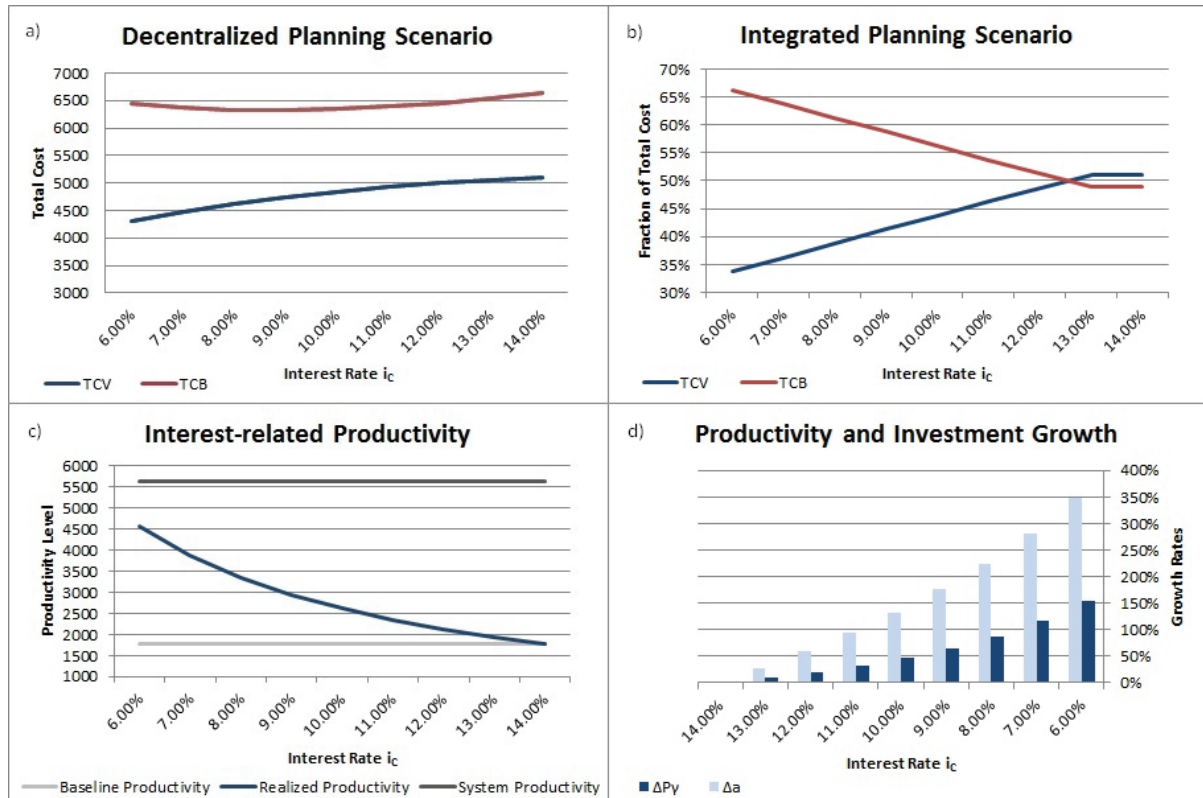


Figure 1: Impact of interest agreement

Results also show that lower  $i_c$ -values encourage productivity and investment growth (cf. Figure 1d)). This is interesting, as observing less than the buyer's optimal  $i_c$ -values may be beneficial for the supply chain in the long run. Perhaps a multi-objective function in which total cost is one component and growth and productivity are other components may be developed in a future work as a strategic tool for long-term investment management in supply chains.

## 5. CONCLUSION

This paper studies integrated inventory and financing decisions in a two-stage supply chains. A large and well-established buyer sources some strategically important components from a rather small supplier. As the supplier very limited in financing expensive investments is due to high loan rates, the buyer may substitute bank lending by directly financing the supplier's investments. This helps to improve overall supply

chain performance. Numerical examples have shown that both, the supplier and the buyer, benefit from such an agreement leading to significant cost reductions in the supply chain. In addition, it could be shown that depending on the agreed interest rate, approximately 70% of the cost and productivity gaps between individual and integrated decisions can be closed by such an arrangement. The allocation of cooperation gains was shown to be dependent on the contracted interest rate between the supplier and the buyer. One limitation of the proposed approach is that capital was assumed to be available without limitation. Thus, considering budget constraints (cf. Hong and Hayya, 1995) may facilitate further insights. Other extensions could also include the study of different shipment structures (cf. Yang and Pan, 2004) or the consideration of uncertainty in demand and its effects on the credit structure.

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# **PRODUCTIVITY BENCHMARK FOR LOGISTICS SERVICE PROVIDERS**

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## **Need for benchmarking of LSPs**

Min and Joo (2009) show an increase in outsourcing of logistics activities, but also predict a shake out of LSPs which can't cope with the dynamics of the market. One way of improving LSP efficiency and competitiveness, is to emulate best practice LSPs. Benchmarking is crucial since LSPs have to outperform their competitors to retain their shipper and market position. DEA is a proper technique for benchmarking as it determines which are the 'best-practice-LSPs ', i.e. using least resources to provide service at or above standard, and less productive ones, i.e. their excess of resources or excess capacity to increase output (Sherman and Ladino, 1995). This paper addresses two issues: homogeneity and use of physical measurements for inputs and outputs.

## **Measurements for productivity in logistics**

Traditionally benchmarking in warehousing and distribution focused on comparing on:

- operating costs, i.e. warehousing or distribution costs as percentage of sales
- operating productivity, i.e. units (e.g. orderliness, cases) handled per person-hour
- intangibles, e.g. response time, shipping accuracy (Hackman et al., 2001).

However, assessing performance on such ratio-based metrics is inaccurate and inappropriate for many reasons, such as: operating costs vary with the price of products, productivity varies with level of technology applied, different customers have different requirements (Hackman et al., 2001). Many studies on productivity combine physical input output data with monetary ones (e.g., Min and Joo, 2009). Defined this way inputs and outputs are measured based on both quantities of inputs e.g. labor and its price. Any change in the value may arise from either quantity or price. In industries with a strong emphasis on cost reduction the price component may be more often used than process improvements to create a cost advantage. Within DEA, the focus rests on determining the technical efficiency, i.e. the physical amount of all input used to produce a product.

## **Defining physical inputs and outputs**

Hackman et al. (2001) distinguish three types of inputs: labor, space and equipment. Labor is the sum of direct and indirect labor hours expended during operations needed for the logistics services provided: warehousing, transportation or cross docking. Space

is less straightforward as it looks, is it square or cubic meters, or is it square meters multiplied by the number of levels in use? We chose direct labor as the proxy to measure labor. Equipment is even more complex to proxy let alone to measure. Material handling, storage and transportation require different types of equipment which cannot simply be summed, e.g. 5 shelves plus 4 trucks. Replacement costs for equipment could be another proxy, but what about depreciation, rental costs and fully depreciated equipment (Hackman et al., 2001)? We chose energy as the proxy for how much equipment is used.

Furthermore measurement is not that straightforward. Data are often difficult to retrieve. Johnson & McGinnis (2011) choose self-reported data, but this is particularly a concern as DEA is a deterministic analysis, as recognized by them. If observations are included in the analysis that contain misreported data or are not measured correctly this could be detrimental to DEA.

Moves in a warehouse consist of both inbound and outbound activities with numbers of orders, orderliness, full or broken cases and/or pallets separated by the goods kept in stock. Moves in transportation are about quantities carried from one site to another destination with zero or some stops in between. Quantities can be full or less than full truckloads. Hackman et al. (2001) finally distinguish storage as an output, i.e what does it take to be able to store the inventory. Pallets have a fixed size and hence require a fixed amount of space, for broken boxes it is more difficult to proxy what it takes to store them. Cross dock is about the number of pallets processed in total in the facility? For all operations we expect economies of scale.

	<b>Warehouse</b>	<b>Transport</b>	<b>Cross-dock</b>
<b>Input</b>	(m <sup>2</sup> storage area) * (number of levels 1,6 m)	m <sup>2</sup> trailer fleet	(m <sup>2</sup> crossdock area) * (number of levels 1,6 m)
	MJs used	MJs used	MJs used
	Number of direct FTE	Number of direct FTE	Number of direct FTE
<b>Output</b>	Number of pallets processed and stored	Number of pallets transported	Number of pallets processed
	Number of complete orders	Km's driven	Number of complete orders on time
	Number of order lines	Number of stops	Number of order lines

Table 1: Inputs and outputs measurements for LSPs

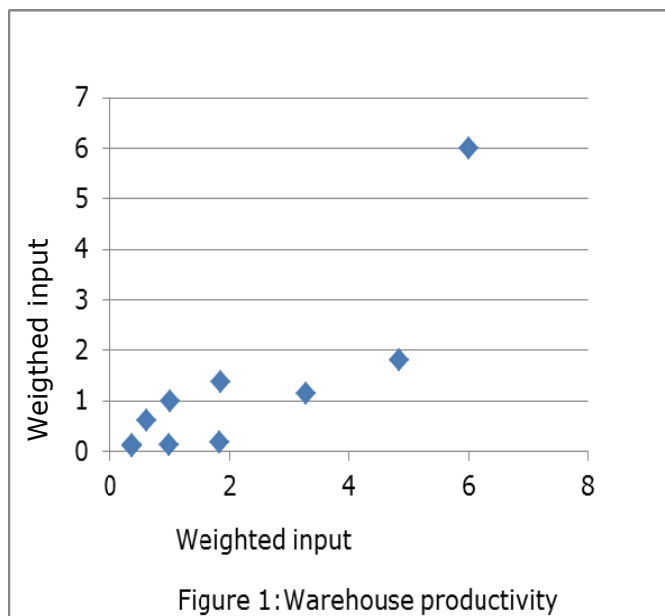
The productivity bench analysis (PBA) proposed here is part of a longitudinal research project on implementing lean management in LSPs. In the project analytical tools and

training materials are developed and applied. These tools are used to develop an improvement agenda. Based on the partial efficiencies companies can determine which input needs improvement measures first. All data used are collected in house by researchers using a standardized approach. The PBA has been used for three years in, in total, 26 LSPs, although not every year in every participating LSP. For cross-dock operations 9 out of 12 companies could not provide data on number of complete orders on time and number of order lines. For the DEA of this group of LSPs we decided only to use number of pallets as output measurement.

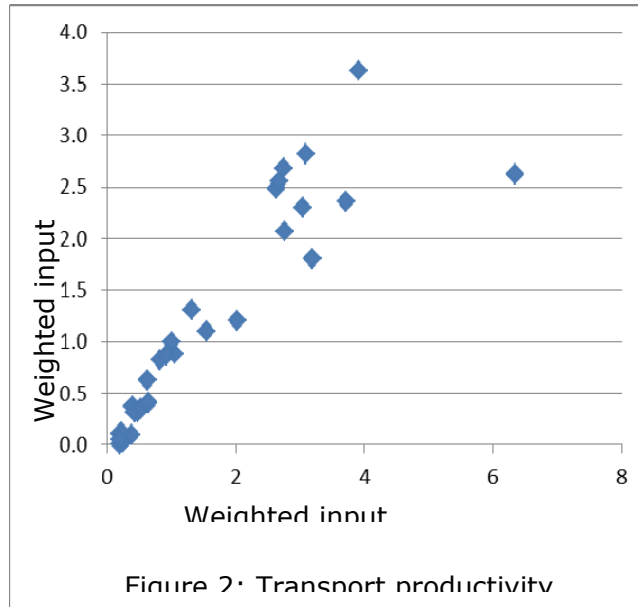
### Results DEA

DEA presents relative productivity for companies in a homogeneous group of firms. The maximum score is 1 and the other firms will show a score between 1 and 0. The companies with score 1 are best in class and others should try and improve.

From 11 warehouses 3 scored the maximum 1 for productivity and form the productivity border. The lowest score in this group was only 0.1 and the lowest but one 0.13, showing a lot of room for improvement. Figure 1 shows the overall productivity analysis for the warehouses.



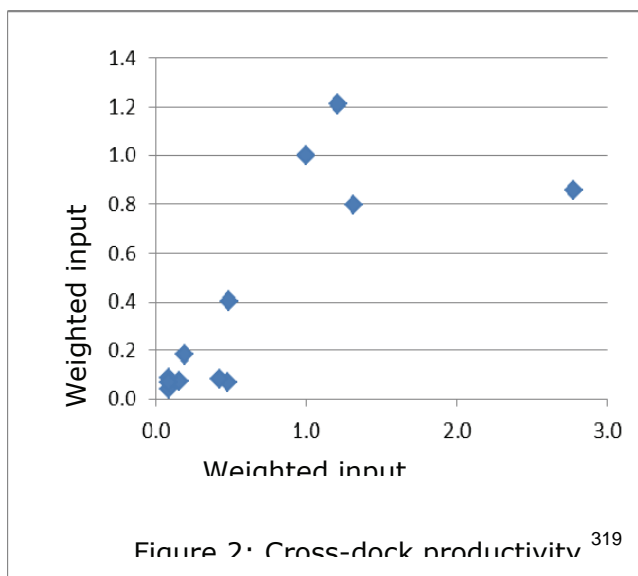
Despite the very low scores, the company with the lowest scores did not score lowest on all partial efficiencies. Sometimes their score ranked 4 or 5 when compared to the other warehouses. For example the weakest warehouse processed 7.38 order lines per hour, whereas the lowest but one processed only 6.15. On the other hand the best companies did not score best on all the partial efficiencies. For example one of the best processed only 6.91 order lines per hour and ranking only 9<sup>th</sup> among the 11 warehouses.



Other partial efficiencies show a similar pattern. This has some important implications for the warehouses involved. As the weakest and weakest but one score weakest on all partial efficiencies related to pallets they might concentrate on how to reduce the input to process the pallets, as such efforts will contribute most to improve overall productivity. On the other hand, the best companies can even further improve their overall productivity by improving their weakest partial efficiencies compared to the other companies. The warehouse with 6.91 order lines per hour for instance

could concentrate on reducing inputs for the order lines as it scores low on all 3 partial efficiencies involved. Consequently, the productivity border might move upwards. A final remark could be on different scores for order and order lines respectively as outputs. The warehouse with 6.91 order lines per hour also scored low on all partial efficiencies related to orders. But another warehouse with the overall score 1, scored high on order lines but average on orders. These could be caused by the complexity of the picking process: more order lines per order may reduce the time needed per line because of less travel time.

From the 31 transportation providers 4 scored the maximum overall score of 1. Here the lowest score was only 0.04 and the lowest but one 0.1. These results show even more room for improvement than in the category warehouses. Figure 2 shows the overall productivity analysis for the transportation providers.



In this category, the weakest provider processed, for instance, only .67 pallets per hour whereas the weakest but one processed 8.31 but the best score was even 33.42 pallets per hour. However, not all of the best overall performers had such a high score as the others scored 10.63, 8.01 and 2.59 respectively. The providers with 8.01 and 10.63 processed 1315 and 1215

pallets per m<sup>2</sup> respectively, whereas the one with 33.42 per hour processed only 613 per m<sup>2</sup> but the weakest but one and the weakest only 147 and 27 respectively. Again these mixed results provide options for improvement for all providers involved. Here the relationship between distance travelled and number of stops can have a similar consequence as the number of orders and order lines for the warehouses. More stops could mean less energy per stop, but more on longer distance because less optimal speed.

From 12 cross dock providers 3 scored the maximum score of 1. Here the lowest score was 0.145 and the lowest but one was 0.197. These results show a smaller difference between the best and the weakest performers compared to both categories. Figure 3 shows the overall productivity for the cross-dock providers.

The weakest and the weakest but one provider scored also lowest on most of the partial efficiencies, e.g. 21 and 57 pallets per m<sup>2</sup> and 0.07 and 0.09 pallets per MJ. Of the 3 best performers 2 ranked high on energy use, 1.4 and 0.92 pallets per MJ, but low use of space with only 118 and 97 pallets per m<sup>2</sup> respectively. However, the third best performer scored best on use of space, 257 pallets per m<sup>2</sup>, but was average on energy use: 0.4 per pallet. The cross dock providers could increase the overall productivity if they manage to achieve the current best performance: 257 pallets per m<sup>2</sup>, 269.1 pallets per hour and 1.4 pallets per MJ.

## **Discussion**

For the companies the retrieving data on inputs and outputs turned out to be quite a cumbersome job. Even companies reporting for the third time still had difficulties in retrieving the standardized data.

The homogeneity varies slightly across the different types of LSPs. Some exceptions but they don't seem to be troublesome. Where we expected differences in productivity between regional and international transport this does not show in the DEA.

The companies did however find it useful to gain insight on the partial efficiencies as these give them a good understanding of the possible improvements that can be made within their own operation.

Despite the emphasis in literature (Hackman et. al., 2001; Min and Joo, 2009) on the necessity of financial aspects of proxies for, for example, equipment, it proved to be possible to formulate all the input in physical terms. This helped to avoid ambiguity in the measurements and hence the interpretation.

We checked for any scale effects. For transport and cross-dock operations the correlation between size and overall efficiency is positive and significant. However for warehousing we do not find a significant relationship. Scale effects seem to occur in transport and cross-dock operations but for warehousing such effect does not occur.



## Conclusion

The need for homogeneity may lead to small sample sizes, i.e. no benchmarks for LSPs but a comparison per specialist in this industry.

For all providers we could identify physical proxies and measures as the DEA approach requires because of its deterministic character and need for data measured exactly.

The retrieval of the data was possible but problematic, except for cross-dock operations, where some outputs could not be measured. It shows how little attention LSP pay to monitoring the productivity, despite the tough competition in the industry. The use of physical measurement data proved to be very helpful in assessing the improvement agenda. Individual partial efficiencies could easily be compared with the other companies (anonymously). It showed to be supportive to logistics service providers in gaining insight on where to improve in their operations.

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## **SUPPLY CHAIN KPIs AND THEIR ACCURACY OF MEASUREMENT: A CASE STUDY AT A MANUFACTURING COMPANY**

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### **ABSTRACT**

Performance measurement (PM) has become one of the most important management tools in the last two decades. A lot of research has been done on the initial stages of PM such as its strategic value, measurement system approaches and the design of key performance indicators (KPIs) without a post implementation look e.g. questioning the accuracy of performance data (PD) measured. The underlying motivation of this paper is that PD in PM not reflecting actual performance attainment is useless and even creates operational inefficiencies that might threaten the survival of a company.

By developing a performance data audit framework (PDAF) based on standard audit principles, we created a road map for managers how to cope best with suspicious PD. The application of this framework to a case study at a manufacturing company shows a necessity to perform such an audit on a regular basis. Furthermore, recommendations of how to mitigate PD limitation issues in general are given. In our case study, PD of the company did not reflect actual performance attainment but this could be corrected by employing the PDAF approach as developed by the authors.

Therefore main lessons learned are that management should be aware with regard to suspicious PD in PM. This requires the development of an audit framework being able to detect inaccurately measured KPIs and allow corrective action to enhance their ability to assess real performance of company activities and in turn increase their competitiveness. The need of auditing PD with regard to whether it is accurate or not has both practical implications for both management practice and research in the field of PM.

### **Introduction**

Supply chain performance measurement has moved into the focus of managers as operations tend to become more global and outsourcing became an integral part of their operations. These new perspectives called for new metrics or KPIs in PM to utilize available resources more efficiently, improve product and service quality and ultimately enhance competitiveness of their company. Once PM systems are in place, KPIs serve as an evaluation basis for performance of employees, functional areas, business units and/or whole organizations. A lot of research has been on the initial stages of PM so far, but as "[o]ne goal of performance measurement is to create usable information for improving the operational efficiency and effectiveness of service delivery" (Rivenbark &

Pizzarella, 2002) one question remains virtually unanswered in the present literature: How accurate are such KPIs actually measured?

This question pertains to a concept of KPI validity and verification as pointed out by Baird (2004, p.4) or Divorski & Scheirer (2001, p.85). There, accuracy is defined as "[t]rue indication [...] of the actual level of performance attainment" (Baird, 2004). Therefore, an accurate measurement of KPIs forms a crucial part of confident and correct PD assessment and evaluation, which in turn is a necessity for every PM system. This requires the development of an audit framework applicable to PD captured. Detection of inaccurately measured KPIs and corrective action to have them measured accurately will enhance manager's ability to assess performance of all supply chain activities and in turn increase the competitiveness of their company.

In the remaining, first a brief introduction to PM and internal auditing is provided, before it is shown how the existing gap between these two can be bridged. Then general problems coming along with auditing of PD are discussed and an improved PDAF based on standard audit principles is developed and its successful application shown in case of a manufacturing company. Finally, the paper closes with some concluding comments.

## **Performance Measurement**

PM and KPIs is a so called "hot topic" on the supply chain management agenda and has received a lot of attention in the management literature since the late 1990s (e.g. Kaplan & Norton, 1996). Traditionally, PM approaches were solemnly focused on financial aspects. However, as new forms of organizations developed and activities such as manufacturing and logistics have become more global in nature the focus of PM also shifted. In this context, PM serves as a tool to satisfy a new need, namely the need to adequately assess and evaluate performance of every aspect of a company's business and its supply chain (Kaplan & Norton, 1996). PM is seen therefore today as a very important function in every company as it gives managers necessary information for decision making and thus a basis for effectively managing their company and its supply chain, or shortly expressed: "No measures, no improvement" (Kaplan, 1990). In this sense PM can be defined as "the process of quantifying the efficiency and effectiveness of an action" (Neely et. al., 1995). Furthermore, it "enables informed decisions to be made and actions to be taken, because it quantifies the efficiency and effectiveness of past action through acquisition, collation, sorting, analysis, interpretation and dissemination of appropriate data" (Neely, 1998).

Moreover, to be a basis for decision making any PM system is also "vital in strategy formulation and communication and in forming diagnostic control mechanisms by measuring actual results" (Wouters, 2009). Hence, PM is not just about measuring performance, it is essential in strategy formulation and control and also pertains to political and behavioural issues within a company. Finally, the value of any PM system lies in the informational content of its measurements and the conclusions managers can draw from this information.

In his work, Erdmann (2003, p.92) pointed out some duties with regard to PM:

- Setting of performance targets
- Selection of performance measures
- Exact definition of performance measures
- Determination of data collection methodology and control of the information flow
- Determination of measurement intervals
- Maintenance of performance measures
- Reporting of results

By looking at Erdmann's (2003) outline of these duties with regard to PM it becomes obvious what we are talking about in this paper. Maintenance of performance measures and KPIs is one of these important duties which, unfortunately, had received little attention so far.

## **Internal Auditing**

Another aspect of company management is auditing, which can be defined as “a systematic process of objectivity obtaining and evaluating evidence regarding the current condition of an entity, area, process, financial account or control and comparing it to predetermined accepted criteria and communicating the results to the intended user” (Kagermann et al., 2008) with predetermined accepted criteria being set via compliance policies, guidelines and regulations. In this context, internal auditing - as opposed to external auditing - is conducted by the companies’ own employees. Such an internal audit serves multiple purposes. At the forefront are assurance services internal auditors perform for the management of a company. Assurance based services are defined as “independent professional services that improve the quality of information or its context for decision makers” (Colbert, 1998). These audits are classified in so called audit fields. Audit fields represent the breakdown of an organization into a set of separate audit areas and form together a so called audit universe. For the purpose of this paper the following breakdown in audit fields and objectives as outlined by Kagermann et al. (2008) is used:

- Management audits: compliance of management with policies and procedures
- Operational audits: processes and workflow structure of organisations
- Financial audits: examination of financial and accounting data
- IT audits: alignment of systems and processes with IT
- Fraud audits: identification of organizational and process weaknesses
- Business audits: to ensure guidelines are followed by a company and third parties

Especially meaningful are operational audits as they may address all issues along a supply chain and/or workflows within a company. The main objective is to improve the supply chain and/or workflows and to ensure that organizational structure, individual processes and transactions are compliant with relevant rules and regulations. Auditors can take a process oriented approach either analysing entire supply chains and/or workflows or focusing on discrete processes or organizational items of a company. The information obtained from such audits should be in both cases used to improve the efficiency, security and reliability of the objects under audit.

### **Bridging the Gap between Internal Auditing and Performance Measurement**

It has been mentioned that PM is the foundation for management to make informed decisions about actions to be taken to improve efficiency and effectiveness of operations increasing the competitiveness of their business. KPIs and PM quantify efficiency and effectiveness for management in a few figures.

Verifying the accuracy of PD and issues related to data quality and its impact on KPIs is receiving very little attention in the management science literature (Grigori et al., 2001, Rivenbark & Pizarella, 2002, Masayna et al., 2007). Where as financial information such as reported profits are audited on a thoroughly and regular basis and legislation in this regard is very strict (e.g. the Sarbanes-Oxley-Act of 2002), reporting on operational achievement is seldom questioned. But in a survey by Barrett & Greene (2000) managers and legislators have stated that the main reason they do not use operational PD is that they do not trust the accuracy of those figures they get.

Auditing of PD does not only ensure that the benefits of creating the data outweigh its costs and that operational inefficiencies are avoided, it also gives managers a greater understanding of process dimensions and procedures to produce PD. Managers and employees gain an overview of the importance of processes they are executing. Considering the Hawthorne Effect, managers and employees will also improve in process execution performance, because they know, that they are being monitored (Shorosh, 2011). A continuous and formal PD audit process therefore ensures that employees practice processes as intended and avoids PD to become less reliable over time.

### **Foundations of Performance Data Audit Frameworks**

As already indicated before, research on the topic of PD quality and auditing of PD has not been addressed in management literature to an adequate extent. To the knowledge

of the authors, only two works (namely Rivenbark & Pizzarella, 2002 and Divorski & Scheirer, 2001) have addressed this topic explicitly which were discussed in the following.

First, Rivenbark & Pizzarella (2002) suggested a PDAF as a post implementation framework intended to conduct a PD audit once a PM system is already in place and PD quality issues come to the fore. It was initially designed for governmental organisations and is based on a standard audit roadmap with phases of planning, preparation, execution, reporting and follow-up (Kagermann et al., 2008). The major drawback on the PDAF suggested by Rivenbark & Pizzarella (2002) is that it is a very generic framework without an advice how to implement and evidence of its applicability. In essence, it does not pay attention to two major pitfalls in the development of PM systems as identified by Theurer (1998):

- There must be a strong commitment from leaders to move toward measuring performance and not just collecting data
- Employees must be able to develop measures or they will use whatever is available

Furthermore, the approach by Rivenbark & Pizzarella (2002) has a pure focus on assessing PD quality and based on this assessment, recommendations are made on how to overcome these data limitations. These recommendations are accompanied by implementation guidelines and a follow-up audit is scheduled to check whether the recommendations have been implemented. Neither a focus is set on building a working environment to foster PD quality nor is the aspect of paying attention for accurate PM addressed. Similar to a standard audit roadmap it points out how to conduct an audit, what steps and in which sequence they have to be performed.

During a survey of verification and validation of strategies of six US federal agencies, Divorski & Scheirer (2001) identified four general approaches to data verification, namely:

- Forstering organisational commitment and capacity for data quality
- Assessing the quality of existing data
- Responding to data limitations identified during assessment of data quality
- Building quality into the development of PD

Doing this they explicitly addressed these two pitfalls mentioned by Theurer (1998) before and presented approaches found in practice to tackle these problems. Furthermore, they pointed out that securing management commitment to data quality and communication of this valuation may overcome the facts of inaccurate PD. Training of employees to equip them with knowledge and ability to understand PM and its implications is also a central point of their framework. However, Divorski & Scheirer (2001) failed to present a structured audit roadmap on how to implement one of their four approaches to data verification.

### **An Improved Performance Data Audit Framework**

The improved PDAF proposed in the following is based on a standard audit roadmap, too, but will be adjusted to the specific needs of PD auditing by incorporating lessons learned from the works by Rivenbark & Pizarella (2002) and Divorski & Scheirer (2001).

Accordingly, it starts with a "planning" phase. An audit is either initiated as part of annual audit plan or via an audit request by any PD stakeholder to the audit team. For either type of audit the audit scope has to be identified, which is done in advance of an annually scheduled audit and for an ad-hoc audit after an audit request has been received. It has to be defined in terms of an audit area under review as for example sales department and a breakdown of a core scope into individual audit segments. Here it is important to create an agenda by specifying when and which segments are to be audited. Furthermore, the creation of a first relationship matrix to point out which processes affect which operating unit and a second one to show which audit objects affect which process can be very helpful. Moreover, a preliminary audit schedule should be developed, which serves as an overview of the audit to be conducted for communication purposes in the next phase.

In a "preparation" phase, the audit team announces to the audit area under review. Furthermore, an audit announcement is distributed which entails a high-level overview of the audit to be conducted supplemented by a preliminary audit schedule. It should also clearly state the audit objective and scope. It enables managers and line employees of a division or department to incorporate this audit in their schedule and to make sure that relevant personnel and documents are ready and available during the audit. After the audit announcement a kick-off meeting with relevant managers and line employees in this context should be held. This meeting is used to discuss the audit process, the identification of roles and responsibilities and to answer questions by the audited areas. Moreover, there should be an assignment of responsibilities with regard to the various aspects of data capturing which really facilitates implementation of recommendations after the audit. It also will likely result in higher quality PD in the future, since employees know for which aspect of PD capturing and maintenance they are responsible for. In case such an audit involves functionally and/or geographically dispersed areas, management should facilitate a companywide coordination and cooperation among them. This is essential to ensure that PD is consistently measured among these areas based on the same definitions and standards. Of course, such a kick-off meeting may also be used to obtain feedback from current PD users and other stakeholders, since they can share valuable experience about strengths and weaknesses of the present supply chain, workflow or process structure and existing PD capturing.

Thereafter, a working program for the audit is created dividing all the audit materials into small workable packages and point out what has to be done with regard to each package. Furthermore, it has to be outlined which key scopes are audited and a clear definition of its processes and objects, what test procedures/fieldwork activities will be used and the required documentation.

At the beginning of the "execution" phase and before starting of fieldwork activities the work program is communicated to the managers and line employees of each audited area in order to enable them to gather required documents beforehand and synchronize their time schedules with regard to the audit. Afterwards the audit team can start with its fieldwork activities designed to produce evidence to meet the objective of the audit. The PD obtained should be able to deliver viable information for the auditors on the processes and other audit objects as defined before. With regard to an operational audit, the most suitable fieldwork activities are document analysis, data sampling, analytical procedures, walk-troughs', direct observations and interviews. These fieldwork activities have to be well documented in working papers, which are a basic requirement of every audit which allows it to assess the audit quality afterwards. They have to outline the object audited, the specific fieldwork activity done and the findings/observations made there. Depending on the informational needs items such as potential risk of future data quality problems or recommendations further improvements may be included.

With the end of the "execution" phase, a "reporting" phase starts. Here, the audit team compiles first a draft version of the audit report which consists of an implementation report as well as a management and board summary. It is based on the working papers made before and has to contain a precise description of the objects audited including its processes and PD sources, an overview of the findings with regard to each audit object, recommendations of what has to be done with regard to the findings, implementation guidelines for recommendations and a conclusion. Additionally, such an audit report has to report about PD limitations and their implications for assessing performance. By explaining how they impact performance assessment, managers and line employees of the audited areas obtain an understanding of the importance and necessity to focus on PD quality. The management and board summary represents a brief summary of the audit report tailored to specific informational needs of both stakeholder groups. The audit report drafts are then submitted to the relevant target groups allowing them to study the reports for themselves. With completion of the audit report draft, a final meeting has to be scheduled serving as a forum to discuss the findings, recommendations and implementation guidelines stated in the audit report. This meeting should also be used to discuss methods to incorporate mechanisms of PD quality assessment into the normal work flow structure of the company. This is especially

appropriate when PD is derived from an IT system. Based on findings, recommendations and the possibility to incorporate PD quality assessment, trainings with relevant employees have to be scheduled to foster capacity and knowledge among employees. After the final meeting, recommendations and implementation guidelines have to be updated and the audit report has to be finalized.

During the final meeting a "follow-up" phase will be scheduled. It serves the purpose of verifying whether the recommendations in the audit report have been implemented as suggested and relevant trainings have taken place. This follow-up phase may uncover a need to execute further fieldwork activities or to repeat the audit due to failure of implementing the recommendations as suggested.

## **Case Study**

The aforementioned improved PDAF framework was successfully applied to a manufacturing company ("The Company") with a dispersed production network across Europe experiencing several problems in their operations. "The Company" is concerned with unacceptable long lead times and out of stock situations. An extensive supply chain survey at "The Company" uncovered that high variability in demand as well as varying delivery performance are the root causes of all these problems. Accordingly, "The Company" developed four supply chain initiatives, namely improved demand forecasting, complexity management, service level agreements and the implementation of a performance management tool plus additional KPIs. The goal the later was to create a PM system with all relevant KPIs for its plants, to develop a consistent definition and performance target for all KPIs, to improve transparency of supply chain performance of all plants and to be able to compile an overall report on KPI performance. In order to achieve all these goals "The Company" had to undergo two major changes. First, its sales order process had to be harmonized among all plants to allow a consistent PM of all plants. Second, a new set of KPIs had to be introduced as existing KPIs did not measure supply chain performance due to their financial focus. As the accuracy of these new KPIs depend primarily on a correct execution of the new sales order process by their sales office employees, the management of „The Company" doubted its accuracy as some of them showed an unexpected low performance.

Accordingly, the core scope of this exemplary PDAF shown in the next section were sales offices and the key scope was the new sales order process. The audit object was a KPI called "In Time Delivery Reliability" which is defined as the deviation between promised and actual delivery date which should give an indication how well "The Company" performs towards its customers. The audit objective was then to obtain evidence on whether it was measured correctly and so the new sales order process behind it is handled correctly.

## **Exemplary Field Work Activities and Findings Thereof**

To find out whether the new sales order process was handled correctly or not and whether the KPI was measured accurately, tests were defined during the field work activities of the PDAF. Some of them entailed hypotheses of an expected value the KPI should obtain and could be tested statistically. Some other tests were exploratory analyses of the PD and proved whether some part of the process is executed correctly. The logical order of the following tests resembles a drill-down into the PD delivered by the ERP system of "The Company". Hypotheses about the PD have been developed together with the management of "The Company" and reflect how it expects the data to "look like" which are based on its experience and subject to the subjective perception of the participating managers. Initially, the following set of hypotheses were tested:

*H1: There is no difference in the KPI performance between the plants*

The underlying assumption of H1 is that, given that there were no major disruptions in the production or a raw material shortage for last six months, all sales offices should

show the same level of performance, if they utilize the new sales order process correctly. Tested by means of a chi-square test for homogeneity it had to be rejected so that the performance of the KPI was found not to be equal.

*H2: There is no difference between all plants in the KPI performance with regard to a certain product category*

The assumption of H2 is that sales offices should have the same performance across all product categories, because in the new sale order process all products were treated the same way. It was also tested by the means of a chi-square test for homogeneity and it was rejected in all cases which gave again a strong indication that the sales offices do not consistently execute the new sales order process.

*H3: There is no difference between sales offices in the KPI performance with regard to destination country*

Almost identical to H2, H3 gives an indication the correct date is employed on a sales and per ship to country level. It was also tested by means of a chi-square test for homogeneity and here only the hypothesis that the performance is equal with regard to one destination country was rejected.

As these initial statistical tests justified doubts in the accurate measurement of the KPIs more tests were conducted to drill further down into the PD of „The Company“. A natural next step of further testing was then just to look on the histogram of late or early deliveries of sales orders, which should be centred on an expected value of 0, meaning that goods have been delivered on-time. This was obviously not the case and in addition to this, a significant amount of orders were classified as “not confirmed” or the delivery quantity asked for was not acceptable.

As the new sales order process required sales office employees to change delivery date requested by the customers on sales order item level if it differs from other sales order items in there, a simple explanation for a significant amount of orders being not on time could have been that they did not change the delivery date on a sales order item level accordingly. For this analysis a change-log file from the ERP system of “The Company” was inspected, listing by default every sales order item at least three times - once for opening a sales order, once for entering a quantity and a confirmed delivery date and once for closing the sales order which leads to

*H4: Changes on Sales Order Item Level are larger than 3*

The assumption of H4 is therefore that the average number of changes on a sales order item level should be significantly larger than three given the sales office employees entered correct delivery dates on a sales order item level. This hypothesis was tested by means of a one-sided t-test which could be rejected in all cases. This in turn was a strong indication that the reason for the significant amount of late and early deliveries cannot be due to failure to change a delivery date on a sales order item level.

Another possible explanation for the significant amount of late deliveries could lie within orders that were confirmed for a week and not for a certain day. Those orders confirmed on a weekly basis should be confirmed for the Monday of the respective week, so that deliveries up to + 4 days late are still considered to be on time. But up to 79% of these orders were correctly confirmed for the Monday in the respective week. However, up to 20% of the orders are incorrectly confirmed for the rest of the days during a week.

Another source for a bad KPI performance could have been that a delivery date was not confirmed at all. Actually the new sales order process required every order to be



confirmed by the sales offices. Therefore there should be no sales order in the KPI that are not confirmed. A closer look on the number of not confirmed orders by confirmation type (a week or certain day) revealed that at least some sale offices very often did not confirm orders at all. This again is in the new sales order process not allowed and reduces accuracy of PD significantly.

Based on the field works activities, strong evidence has been found that at least some sales employees do not execute the new sales order process correctly and therefore accuracy of PD is low. This results to the fact that the associated KPI "In Time Delivery Reliability" is not measured correctly as it does not reflect the current performance attainment of "The Company".

After conducting these fieldwork activities employees have been confronted with these findings. Due to the engagement of the top level management of the "The Company" all of the above mentioned faults of not executing the new sales order process correctly were corrected. Already within one month the KPI "In Time Delivery Reliability" improved significantly and "The Company" decided finally conducting follow-up audits according to the PDAF as described above.

## **Conclusions**

The present work offers a new look at PM systems by questioning the accuracy of PD by means of a PDAF since one of the main goals of any PM initiative is to create usable information which allows to make decisions to improve operational efficiency and effectiveness (Rivenbark and Pizzarella, 2002). For this purpose an improved PDAF based on a standard audit roadmap by Kagermann et al. (2008) was developed which has then been applied to a set of new created KPIs in a production company's sales order process. During field work activities there, severe deviations were uncovered. Of course, as this PDAF was so far only used at one single company, it should be applied to several companies in different industries to prove its general applicability. But given this evidence from a single case study, it is unquestionable that managers should always be aware of potential data limitation issues and incorporate them in their evaluation of PD to be used in KPIs. This holds true especially for PD mainly obtained by means of a manual process. Furthermore, businesses and their processes are subject to change further amplifying the need to audit PD of recently redesigned processes. Finally, since resources have to be allocated to conduct such an audit, tangible as well as intangible savings have to be explored such that managers can easily grasp the potential impact underlining the necessity for a PDAF.

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# **THE RELATIONSHIP BETWEEN CONTINUOUS IMPROVEMENT AND OPERATIONAL PERFORMANCE IN AN EMERGING MARKET: THE CASE OF VIETNAM**

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## **INTRODUCTION**

As firms in Asia's developing countries emerge into the world marketplace they are becoming serious competitors to their western counterparts. However, relatively little is understood about the management practices of these emerging-market competitors, and in particular, about their continuous improvement (CI) practices (White, 2002; Chakravarty *et al.*, 1997). Vietnam is a classic example of this. The country has one of the fastest-growing emerging economies in Southeast Asia. It is the second largest coffee producer in the world, and one of its top ten garment exporters. It is also fast becoming the leading furniture exporter in the Association of South-East Asian Nations (ASEAN). With political stability and a large population of over 92 million providing abundant low-cost labor and one of the youngest workforces in the world, Vietnam is emerging as a favored production destination for companies from developed nations. Firms such as Intel, IBM, Fujitsu, and Canon now develop and manufacture high-tech products in the country's eight technology parks. Yet despite this tremendous growth in business activity, research on Vietnamese management is scanty, and there has been almost no investigation of CI practices. The study reported here aims to increase understanding of Vietnamese business practices. It comprises field research using in-depth case studies to investigate the factors underpinning CI effectiveness and to clarify the impact of CI on operational performance in Vietnam.

## **RESEARCH MODEL**

Continuous improvement practices, such as lean production, quality control circles, total quality management (TQM), and employee idea systems, are broadly defined as the set of principles, mechanisms, and activities aimed at raising the level of organization-wide performance through ongoing, systematic, and cumulative improvements (Lillrank *et al.*, 2001). By involving everyone in CI, organizations can manage and accelerate the learning curve, and thus enlarge the scope of improvement from simple cost reduction to gains in quality, speed, safety, and the work environment (Imai, 1987; Ishikawa, 1985).

The research model in this study contained five factors including top management commitment, management development, the participation of change agents, employee development, and the reward system for continuous improvement.

### **Top Management Commitment**

Deming (1986) and Garvin (1988) have stressed the importance of senior management commitment in achieving high levels of CI and quality performance. Other researchers have also found that senior managers play a critical role in: (1) developing commitment to CI; (2) establishing clear objectives and creating a supportive environment; (3) building and communicating the vision at the start and continuously steering and guiding the CI process; and (4) personally involving themselves in the improvement process (Beer, 2003; Palermo and Watson, 1993). Regardless of the country, and length of the firm's experience of quality improvement, Rao *et al.* (1997) found that top management

support significantly influenced levels of performance in strategic quality planning, human resource development, supplier quality, and overall quality results in firms in Mexico, China, and India. Accordingly, Hypothesis 1 is as follows: *The level of top management commitment is positively associated with CI effectiveness in Vietnamese organizations.*

#### Management Development

Outside of Vietnam, researchers have found that management development is critical for CI implementation and sustainability (Jorgensen *et al.*, 2007). Training can help managers better communicate with frontline employees and create more employee involvement as Terziovski and Sohal (2000) have shown. According to Jorgensen *et al.* (2006), for this to happen managers must (1) commit to ongoing improvement; (2) change attitudes and expectations towards CI; (3) accept and act on all the learning that takes place; (4) provide resources and information necessary to do the job; and (5) participate in the design and implementation of systematic ongoing improvements. Accordingly, Hypothesis 2 is as follows: *The level of management development is positively associated with CI effectiveness in Vietnamese management.*

#### Participation of Change Agents

Outside of Vietnam, researchers have found that implementing and maintaining high levels of CI depends not only on developing managers, but also on forming a *steering committee* or guiding coalition tasked with driving improvement programs. The steering committee's functions are to establish organizational guidelines for the overall approach, to define objectives and set performance measures for the improvement effort, to provide resources for training programs, and to review its status formally (Dean and Evans, 1994; Sohal *et al.*, 1989). More importantly, Kotter (1995) stated that the steering committee must have the authority and resources to lead the change effort; its members therefore must be powerful in terms of titles, expertise, reputations, and relationships. Accordingly, Hypothesis 3 is as follows: *The level of participation of change agents is positively associated with CI effectiveness in Vietnamese management.*

#### Employee Development

Outside of Vietnam, the importance of employee development is well-documented in the literature on CI in the developed world (Crosby, 1979; Gryna, 1991; Deming, 1986). Juran and Godfrey (1999) have found that employee empowerment goes well beyond delegating authority and training, but also encouraging people to take the initiative and broaden their scope, as well as being supported when they make mistakes. By involving employees effectively, companies can develop a shared concern for quality at all levels of the company and enable employees to take responsibility for his or her work and seek improvement (Garvin, 1988). Accordingly Hypothesis 4 is therefore as follows: *The level of employee development is positively associated with CI effectiveness in Vietnamese management.*

#### Reward System for Continuous Improvement

Many studies outside of the Vietnamese context have shown that rewards and recognition help rally employees' commitment to and participation in CI, provide momentum and enthusiasm for CI initiatives, and positively affect a firm's performance (Chin *et al.*, 2002; Crosby, 1979). Bessant and Francis have pointed out (1999) that rewards motivate employees and encourage the behaviors that the organization is trying to embed. Rewards can be based on team or individual performance, the acquisition of skills, the achievement of CI objectives, or the implementation of improvement ideas (Malcolm Baldrige National Quality Program, 2009-2010). Accordingly, Hypothesis 5 is as follows: *The extent to which structured rewards are used for continuous improvement is positively associated with CI effectiveness in Vietnamese management.*

### Impact of CI on Performance

Attaining performance excellence is the primary goal of CI practices. Outside of Vietnam, the manifold benefits of effective CI practices have been reflected in sustained competitive advantage (Garvin, 1987), improved product and service quality (Nair, 2006; Naveh and Erez, 2004; Rungtusanatham, 2001; Schroeder *et al.*, 2005), improved environmental performance (Kleindorfer *et al.*, 2005; Schroeder and Robinson, 2010), and enhanced operational performance (Dow *et al.*, 2009; Choi and Eboch, 1998). In addition, Jorgensen, Boer, and Laugen (2006) have found that CI is significantly related to increased productivity, reduced costs, improved delivery, and decreased employee absence. Accordingly, Hypothesis 6 is as follows: *The effectiveness of CI is positively associated with operational performance in Vietnamese management.*

## RESEARCH METHODOLOGY

This field study adopted a case methodology using a mixed-methods design based on quantitative and qualitative data. A case-study approach is suitable for investigating complex subject matter in which the phenomena of interest are not well understood (Meredith, 1998; Benbasat *et al.*, 1987). The use of mixed methods permits triangulation and complementary overlapping examination of the phenomena, which in turn enhances the scope and breadth of understanding (Creswell, 2003; Boyer and Swink, 2008).

The survey instrument was administered in the form of a questionnaire to frontline employees, supervisors, and middle managers. A total of 660 questionnaires were given out, and 490 people responded (a response rate of 74 percent).

To ensure the unidimensionality of the scales, an exploratory factor analysis (principal components method with varimax rotation) for each construct was performed. After the factor analysis, an indicator item was analyzed and if necessary deleted in accordance with the literature (Johnson and Wichern, 1998; Hair *et al.*, 1998; Chen and Paulraj, 2004). All alpha measures were larger than the threshold value recommended by Nunnally (1978) and Flynn *et al.* (1990), and suggest that the constructs are reliable.

Following the suggestion of O'Leary-Kelly and Vokurka (1998), we assessed the convergent validity by using confirmatory factor analysis (CFA). The model fit the data well based on threshold values suggested by Hu and Bentler (1998) ( $\chi^2/df = 1032.5$ ,  $TLI = 0.936$ ,  $RMSEA = 0.054$ ,  $CFI = 0.944$ ). All factor loadings in the CFA model are greater than 0.5 and the t-values are significantly greater than 2.0, ensuring convergent validity.

Hierarchical multiple regression was used to examine the effects of top management commitment, management development, change agents, employee development, and the employee reward system on CI effectiveness (see Table 1). Hypothesis 1 predicted a positive relationship between top management commitment and CI effectiveness. Consistent with this prediction, this hypothesis was supported ( $\beta = 0.15$ ,  $p < 0.01$ ). Hypothesis 2 predicted a positive association between management development and CI effectiveness. The regression results support this prediction ( $\beta = 0.20$ ,  $p < 0.001$ ). Hypothesis 3 predicted a positive relationship between the role of change agents and CI effectiveness. This hypothesis was supported ( $\beta = 0.26$ ,  $p < 0.001$ ). Hypothesis 4 predicted a positive association between employee development and CI effectiveness. This hypothesis was supported ( $\beta = 0.21$ ,  $p < 0.001$ ). Hypothesis 5, which predicted a positive relationship between the reward system for CI and CI effectiveness, was *not* supported ( $\beta = 0.07$ , ns).

Variables	Model 1	Model 2
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Controls		
D1	<b>.29***</b>	.07
D2	<b>.33***</b>	<b>.17***</b>
Location	<b>-.30***</b>	-.06
Main Effects		
Top management commitment		<b>.15**</b>
Management development		<b>.20***</b>
Role of change agents		<b>.26***</b>
Employee development		<b>.21***</b>
Employee reward system		.07
$R^2$ (adjusted)	.08	.60
$R^2$	.09	.60
<i>F-value change</i>	15.75	90.91

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Table 1: Regression analysis with CI effectiveness as the dependent variable

We also analyzed the effects of CI effectiveness on operational performance after first introducing the control variables (see Table 2). Hypothesis 6, which predicted a positive relationship between CI effectiveness and operational performance, was supported. The regression results show that CI effectiveness was significantly and positively related to operational performance ( $\beta = 0.65$ ,  $p < 0.001$ ).

Variables	Model 1	Model 2
Controls		
D1	<b>.30***</b>	.11
D2	<b>.34***</b>	<b>.13*</b>
Location	<b>-.39***</b>	<b>-.19***</b>
Main Effects		
CI effectiveness		<b>.65***</b>
$R^2$ (adjusted)	.13	.52
$R^2$	.14	.53
<i>F-value change</i>	25.74	134.13

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Table 2: Regression analysis examining the effect of CI operational performance

In addition to the survey, three rounds of face-to-face interviews with 60 executives, managers, supervisors, and employees at the six case companies who had experience in CI. We also directly observed the production facilities and work offices. Overall, the interviews and observations resulted in a database of 120 pages of single-spaced text. We also collected company documents including CI/quality reports and copies of employee improvement ideas amounting to more than 600 pages of information, charts, and pictures. These qualitative data were analyzed according to steps adapted from the literature (Weber, 1985; Walker, 1985; Miles and Huberman, 1994).

## DISCUSSION AND CONCLUSION

This research tested six hypotheses, and found five that were supported. The results showed that top management commitment has a positive effect on CI effectiveness, suggesting that senior managers are critical to promoting an organization-wide CI

culture, establishing and communicating clear CI objectives, encouraging employee participation in CI, guiding CI through personal involvement, and allocating resources to support CI initiatives throughout the organization. CI success also depends on the level of management development, the activity of change agents, and the level of employee development. This study found that management development has a positive influence on CI effectiveness. This illustrates the importance and value of managers who have extensive knowledge of and training in CI principles and techniques, and who are committed to ongoing improvement by actively coaching, promoting, and sustaining CI initiatives.

The level of activity of change agents has a positive effect on CI effectiveness. The role of change agents is especially important in Vietnamese companies because past economic and political systems have created a culture of collectivism, hierarchy, and consensus. The Vietnamese sense of self is tied to family, friends, and society rather than to work, and Vietnamese culture favors consensus-oriented decision making and values harmony (Shultz *et al.*, 2000). Individuals rarely take independent action, and most people conform to avoid conflict. For these reasons, the role of change agents is extremely important for effective CI in Vietnam. Well-liked, respected, and influential change agents are needed to serve as liaisons between senior managers, middle managers, and frontline employees. Their functions are to communicate the objectives, delegate the work, enforce the initiatives, and ease any anxiety regarding the change effort.

The results of the study also found that employee development positively influence CI effectiveness. This suggests that getting excellent results from CI requires that employees be given work-skills training to help them do their jobs, and an employee idea system that encourages them to find and fix problems by offering improvement suggestions.

Contrary to our initial prediction, employee reward systems did not significantly influence CI effectiveness. Future research could include other tests of this dimension to explore this finding and better understand how CI effectiveness changes depending on the management of employee reward systems for CI in Vietnamese organizations.

Regarding control variables, this study found that respondents from foreign-invested enterprises (FIE) were more likely to find CI effective and facilitates operational performance than respondents from state-owned enterprises. This result supported the argument that the type of business ownership highly impacted CI effectiveness in Vietnamese organizations. FIEs have considerable exposure to global best practices, and they have the resources to transfer these practices to emerging markets. In addition, respondents from companies in Hanoi, compared to respondents from firms in Ho Chi Minh City, were less likely to find that operational performance was improved by CI effectiveness. The explanation is not entirely clear, but a couple of phenomena may have contributed. First, more respondents from companies in Hanoi have bachelor's and graduate degrees (50 percent) than respondents from companies in Ho Chi Minh City (7 percent). This may have made the Hanoi respondents more critical of CI initiatives and results. Second, since respondents from companies in Ho Chi Minh City have been at their jobs on average two years longer than respondents from companies located in Hanoi (respondents from firms in Ho Chi Minh City = 6.3 years, respondents from firms in Hanoi = 4.6 years), they may be more committed to their firm and more positive of the CI initiatives and their company's success.

From being one of the poorest countries in the world, Vietnam has become an active player on the regional and global business stage. Much of this impressive development has been based on the country's supply of cheap labor. Yet as Vietnam continues to develop and faces increasing fierce competition from other developing countries, where wages are just as low or lower, the cost of its labor will not bring the significant benefits

and growth it has in the past. Cheap labor does not offer Vietnam any lasting competitive advantage. Acquiring and deepening CI capabilities, knowledge, and skills will allow Vietnamese companies to build their human resources into trained knowledge-workers whose expertise and insights can enable the country to enter markets for high-value products and services.

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## **MEASURING SUPPLY CHAIN DISRUPTIONS**

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### Measuring Disruptions in Supply Chains

The occurrence of supply chain disruptions has gained a lot of attention during the last years from researchers and practitioners alike. Especially the mitigation and post-disruption management has been dealt with extensively (e.g. Craighead 2007, Tomlin 2006, Sheffi 2005). On the other hand, researchers attempted to quantify the effects of supply chain disruptions to assess their relevancy and impact. This assessment is hereby used to reveal similarities and differences in different types of supply chain disruptions, to prioritize their elimination. Thereby, a variety of measures have been applied.

Hendricks & Singhal (2003) for example try to quantify the effects of disruptions through abnormal deviations of shareholder value after announcements of supply chain disruptions. They concluded that after such announcements, shareholder value decreased abnormally by more than 10%. MacPherson (2008) instead combines estimated sales losses and duration of delays. He concludes that disruptions due to U.S. border inspections have resulted in holding-related sales losses of Canadian food manufacturers by on average 55.000 US\$ per shipment.

However, apart from these examples, general and systematic indicators for measuring supply chain disruptions are scarce. The question therefore rises, how companies should mitigate something they cannot measure. Furthermore, a guideline for an unambiguous deduction of indicators is lacking. Thereby, not only the comparability of research findings is imperilled, but also the certainty that the indicators really measure the desired construct (Kromrey 2009). Furthermore, other indicators might be required, to assess the impact of supply chain disruptions, e.g. regarding the reduction of flexibility.

As already indicated by the example mentioned above, supply chain disruptions can be especially costly in food supply chains, as many food products are highly perishable and require therefore maintenance of optimal conditions during processing, handling, and transport (van der Vorst et al. 1998). Apart of unexpected delays leading to losses, temperature deviations also reduce the shelf life of food products significantly (Nunes et al. 2006). Therefore, indicators may have to be tailored to assess supply chain disruptions in a specific context. Consequently, the intention of this paper is to develop a measurement tool to identify, measure, and analyze supply chain disruptions in food supply chains.

Section 2 focuses on the descriptive research aim, which is to logically deduce starting points to define, describe, and identify disruptions. By starting from a general and abstract description of the phenomenon, the intention is to cover all relevant aspects of disruptions so that any disruption can be identified with the tool. The objective of section 3 is to develop a framework to systematically and extensively describe and identify disruptions by analyzing how its constitutive characteristics can be covered by a general procedure. Thereby, managers and researchers shall be provided with a guideline for how to develop indicators for the identification of disruptions. Section 4 in turn focuses on the pragmatic aim of the paper, which is to set rules and illustrate options for the transfer of indicators into measurements, their interpretation, as well as their

aggregation for further analysis. By the end of the section, a scoring model for measuring disruptions in supply chains is provided, to allow for analyzing supply chain disruptions on a common ground. Section 5 closes with contributions and limitations of this research and indicates opportunities for further research.

#### Identifying Process Plans

As the preceding already indicated, a disruption is a construct, which is not directly observable in reality. Indeed, many definitions exist, which differ in the understanding of supply chain disruptions. For example, Hendricks & Singhal (2005) define disruptions as "*a firm's inability to match demand and supply*" (p. 35), whereas Craighead et al. (2007) define supply chain disruptions as "*unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain*" (p. 132). A literature review conducted by Brenner, Hülsmann & Korsmeier (2012), concludes that the literature at least seems to agree that disruptions are significant negative deviations from the process plans. However, this understanding still leaves space for interpretation and does not allow for a direct observation.

Kromrey (2009) states that tracing such phenomena is only possible via indicators. However, before starting to identify, classify and measure disruptions, one has to make sure that indicators and measures are valid and reliable. Therefore, indicators shall not be picked at random, but deduced from the object of research in a systematic and logical process (Kromrey 2009). In consequence, a scoring model will be developed, to assure the quality of indicators and measures which can be used to identify, measure and analyze supply chain disruptions systematically.<sup>2</sup>

For the development of the scoring model, firstly, the constitutive characteristics of the phenomenon have to be defined (Hülsmann et al. 2006). As a supply chain disruption is basically understood as a deviation from the process plans, these process plans need further specification to identify deviations thereof. According to Remer (2004), process plans can be understood as the chain of operational sub-goals of an organization. If the plans are feasible, the process should therefore be a reflection of the plans. A process in turn normally comprises a set of logically connected activities, which transform inputs into outputs, hence raw materials into products (Cooper, Lambert & Pagh 1997). Basic elements of process plans are thus the planned products (in any processing stage) and the planned logically connected activities. If it is possible to describe the products and activities systematically, it is also possible to draw conclusions on the process plans and therewith, indicators for disruptions might be deduced.

The systematic description of products and processes can be done with the help of classifications (Kromrey 2009), which include general criteria and actual attributes to specify products and processes. For the creation of classes, Bailey (1994) stresses that they must be exhaustive and mutually exclusive. However, he continues that during research the number of different classes can be overwhelming, wherefore frequently only those classes are used, which are relevant for the research question. In the case of food products, various classifications of product characteristics exist (Pennington 1993; Szczesniak 1962; Cardello 1995). Depending on the scope of analysis, these comprise different aspects, as e.g. nutritional characteristics, appearance, or microbiological

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<sup>2</sup> The general approach can be found in Hülsmann & Grapp (2006), who developed a scoring model for measuring the degree of autonomous cooperation in international supply networks.

characteristics. The question is thus, which characteristics of food products are relevant in food chains?

#### Specifying Product Characteristics and Process Activities

Firstly, classes should comprise characteristics, critical for realizing the process plans. Any case, where the food is deemed inappropriate for its intended use, process plans are not met. Secondly, the classification should be easily accessible, usable and widely applicable, to increase the number of users of the scoring model and the comparability of results. Therefore, the classification by LanguaL™ Food Product Indexer is chosen, as it is based on a free access software tool, with a classification originating from international standards, and is widely recognized in research on food products (Pennington 1993; Cardello 1995). Additionally, not only the product is described, but also further information relevant in food chains, as for example the nature of packaging, the preservation method and the region of origin. Thereby, more information can be gathered to specify the process plans.

LanguaL™ was created in the 1970's as a method to automatically describe, capture, and retrieve data about food products. Since then, it has been constantly refined and applied to more food products, as well as other geographical regions. The thesaurus provides a standardized language which systematically describes any food product by a combination of criteria. These are in turn coded for computer processing. The codes can be used to retrieve information on specific food products from external databases, in which currently, about 35.000 food products have been classified.<sup>3</sup>

This list of general criteria can now be used to describe the products systematically, so that insights on product specific process plans can be gained. However, for obtaining exhaustive and mutually exclusive classes, also all potential attributes for each criterion have to be captured. This can be done by transferring criteria and attributes into a morphological box (Andler 2011). By filling the morphological box with all potentially possible attributes of food products as in LanguaL™, products are identified by a combination of one attribute from each criterion.

However, as every class also include sub-classes, which in turn contain a variety of attributes, for the purpose of illustration, only attributes on the second layer of sub-classes will be shown. This reduction of complexity reduces of course the specificity of information. However, the degree of specification depends on contextual requirements (Hahn & Pichhardt 2008) and does not affect the general rules for the development and functioning of the scoring model. The following figure illustrates the methodology of the morphological box for food product characteristics.

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<sup>3</sup> see: Danish Food Information (2012) for further information

**Figure 4: Morphological box for product characteristics based on LanguaL™**

CRITERION	ATTRIBUTES					
A. PRODUCT TYPE [A0361]	FRUIT FRESH OR FROZEN; NUTS [A1221]	VEGETABLES FRESH OR FROZEN [A1227]	PULSES, DRY [A1236]	OILSEEDS AND OILFRUITS [A1237]	CEREALS [A1240]	...
B. FOOD SOURCE [B1564]	ALGAE, BACTERIA OR FUNGUS USED AS FOOD SOURCE [B1215]	ANIMAL USED AS FOOD SOURCE [B1297]	CHEMICAL FOOD SOURCE [B1041]	FOOD SOURCE NOT KNOWN [B0001]	LIQUID AS FOOD SOURCE [B2974]	...
C. PART OF PLANT OR ANIMAL [C0116]	EXTRACT, CONCENTRATE OR ISOLATE OF PLANT OR ANIMAL [C0228]	PART OF ALGAE OR FUNGUS [C0247]	PART OF ANIMAL [C0164]	PART OF PLANT [C0174]	PART OF PLANT OR ANIMAL NOT APPLICABLE [C0005]	...
E. PHYSICAL STATE, SHAPE OR FORM [E0113]	LIQUID [E0130]	NOT KNOWN [E0001]	MULTIPLE [E0108]	SEMILIQUID [E0103]	SEMISOLID [E0144]	...
F. EXTENT OF HEAT TREATMENT [F0011]	EXTENT OF HEAT TREATMENT NOT KNOWN [F0001]		HEAT-TREATED [F0022]	HEAT-TREATED, MULTIPLE COMPONENTS, DIFFERENT DEGREES OF TREATMENT [F0023]		...
G. COOKING METHOD [G0002]	BY DRY HEAT [G0004]	BY MICROWAVE [G0011]	BY MOIST HEAT [G0012]	WITH FAT OR OIL [G0024]	NOT APPLICABLE [G0003]	...
...	...	...	...	...	...	...

As can be seen, the enumeration of possible attributes is not complete for every row due to the already mentioned number of varieties. Nevertheless, the methodology provided by LanguaL™ allows for a comprehensive and systematic description of products, as well as an unambiguous classification. By the codes, any product can be unambiguously identified and differentiated from other food products. The resulting code when combining the respective attribute for each criterion can be used to compare the susceptibility to disruptions across food chains for the same product. However, it should be noted that while moving from one process to the next, the code might change due to applied activities. Additionally, where the level of description needs still further specification, the respective sub-classes may be used.

In other cases, less specification might be required, if attributes are deemed to be less relevant for the process plans. However, in order to correctly describe the product depending on its processing stage, as well as the process plans, also the specific process step has to be classified, which requires an equally systematic approach.

Again, classes should be based on relevant characteristics of supply chain processes, shall allow for a distinction of different activities, as well as different degrees of specification. Again, several approaches could be selected. One option is for example to base the classification on the SCOR model (Supply Chain Council 2010). The advantage of this approach is that it is generic, but its general applicability is also a disadvantage, as it does not provide specific information on processes in food chains, whereby the identification of disruptions is inhibited. Another option is to base the classification on quality management standards dedicated to food chains, such as the International Food Standard (IFS) or the Cool Chain Quality Indicator (CCQI). However, whereas infrastructure and equipment are dealt with in detail, the actual process activities are regarded less (*IFS Logistics 2012; Cool Chain Quality Indicator Standard 2009*).

Due to the lack of such a classification, another approach was used to deduce basic process activities, namely by a content analysis of food chain standards. However, for

such an approach to be successful, different food segments have to be covered, as they pose different requirements regarding handling and processing. Furthermore, standards should be well established, tested and adapted on a global scale, to increase reliability and easiness of use. To assess whether all basic elements of supply chains have been covered, the activities named were grouped into the generic classes of the SCOR model, namely Source, Make, Deliver, and Return.

The basic document for global food chains is the Codex Alimentarius. The Codex Alimentarius Commission currently consists of 185 member countries, covering about 99% of the world population (Codex Alimentarius Commission 2013) and was established in 1962 to guide global food policy (Trienekens & Zuurbier 2008). Since then, the Commission has published about 327 documents, as well as several thematic compilations. Of those, seven publications outline a code of practice in food chains for different groups of products. After an initial analysis, these documents seem to be a suitable starting point, as they cover the entire food chain, are similarly structured, but differ in activities depending on the food groups. The following figure illustrates the general classes of activities encountered in the different Codex Alimentarius guidelines:

**Figure 5: Morphological box of process activities based on Codex Alimentarius**

CRITERION	CHARACTERISTICS							
1. SOURCE	RECEIVING & INSPECTING	RECEIVING & INSPECTING & SORTING		COLLECTING & INSPECTING	GATHERING & INSPECTING	RECEIVING & ANTE-MORTEM INSPECTING	NOT APPLICABLE	
2. STORE RAW MATERIAL	COLD STORING	PRE-COOLING		AMBIENT STORING	DRY STORING	FROZEN STORING	NOT APPLICABLE	
3. MAKE	FISHING & INSPECTING & PACKING	HARVESTING & INSPECTING & PACKING	HUNTING & PARTLY PROCESSING & PACKING	MILKING & INSPECTING & PACKING	SLAUGHTERING & POST-MORTEM INSPECTING & PACKING	EXTRACTING & INSPECTING & PACKING	PROCESSING & PACKING & LABELING	NOT APPLICABLE
4. STORE PRODUCTS	COLD STORING		AMBIENT STORING		DRY STORING		FROZEN STORING	NOT APPLICABLE
5. DELIVER	LOADING, TRANSPORTING, UNLOADING		LOADING, SEPARATING, TRANSPORTING, UNLOADING		PRE-COOLING, LOADING, TRANSPORTING, UNLOADING		TRANSPORTING, UNLOADING	NOT APPLICABLE
6. RETURN	DESTROYING	USING FOR OTHER PURPOSES THAN HUMAN CONSUMPTION		RETURNING TO SALEABLE STOCK		REPROCESSING	NOT APPLICABLE	

The classification of process activities based on the Codex Alimentarius follows the assumption that the guidelines are exhaustive and mutually exclusive. As the commission created one basic text, which is applicable in case no specific guideline applies (*Codex alimentarius. Food hygiene* 2009), this assumption seems to be reasonable. The reason for taking several activities into one field is that according to the Codex, these activities always have to be done for certain products. Nevertheless, the activities named only provide a guideline for the deduction of indicators and can be further specified by e.g. referring to the process flow diagram, which is also mandatory in the Codex.

Both morphological boxes contain now a range of criteria, which can be used to describe the objects as well as to deduce indicators for the identification of food chain disruptions.

### Identifying and Measuring Disruptions

The next step of the scoring model consists in specifying characteristics (Hülsmann & Grapp 2006). In this context, the process plans may be concretized based on the specific product characteristics and the specific process activities. Similar to structuring an organization in a matrix form into tasks (horizontally) and product segments (vertically) (e.g. Reber & Strehl 1988), process plans can be structured based on activities (horizontally) and product characteristics (vertically). In order to concretize the actual process plans, only the actual combination of attributes from the morphological boxes is chosen. In principle, every field of the matrix now represents one part of the process plans, for which indicators for disruptions can be developed.

Since process plans are multidimensional in nature, at least one indicator is required for each dimension, to completely cover the phenomenon (Kromrey 2009). Nevertheless, by trying to cover all dimensions of the process plans, the amount of indicators and the complexity of the model also increase. The deduction of indicators could therefore follow a priorities approach, by firstly covering the most critical part of process plans. Criticality can on the one hand refer to the efficiency loss in a process by a disruption (i.e. impact of disruption), as well as the robustness of the process to disruptions (i.e. probability of disruption). This prioritization can be done following the Analytic Hierarchy Process (AHP) (e.g. Saaty 1982). Thereby, the relative importance of each process step is determined by pair-wise comparison between all steps.

The derived indicators have to be formulated as precise as possible, so that the empirical phenomena can be unambiguously identified (Kromrey 2009). Therewith, it becomes not only transparent how results were obtained, but also the temporal-spatial and inter-personal applicability of the model and comparability of the results is enhanced. Next, the indicators have to be weighted, too. For instance, during processing, the duration of heat treatment could be more critical than the temperature as such. Therefore, the indicators in each field are compared and weighted based again on pair-wise comparison.

Next, each indicator has to be operationalized so that it can be measured (Hülsmann et al. 2006). According to Kromrey 2009, operationalization means a guideline for action for an empirical utilization of terms. This implies a reasoned and documented deduction of measures which are used to make indicators accessible for empirical evaluation. Depending on the nature of the indicator, it can be directly transferred into one measure, or it can be specified into several measures. In general, by using several measures, errors of measurement can be reduced and may allow for an assessment of indicators even though some of the required data is not available (ibid.). Thus, for each indicator, measures have to be derived and weighted by prioritization.

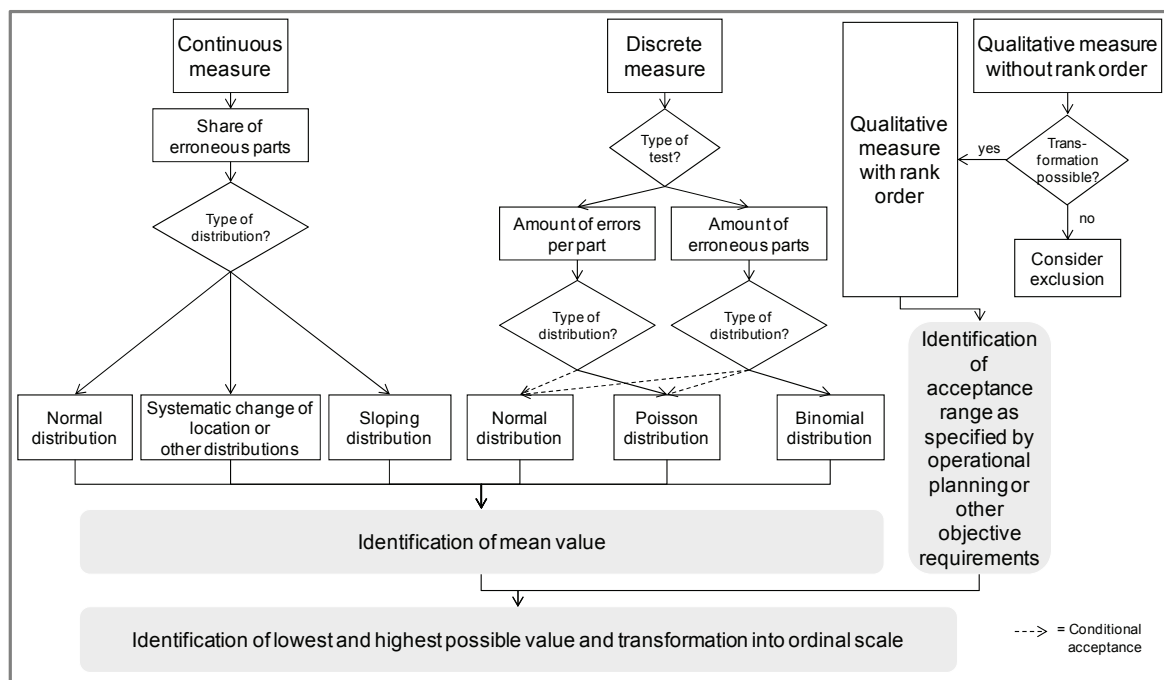
In the next step, the values for each measure have to be obtained from the process documentation or by observation. Once the values of the measures are obtained, the question arises, how to interpret and how to transform them into a consistent measurement model, where values based on different measuring units can be compared. Sources for this information can be e.g. quality control cards, which control processes with the help of benchmarks and critical thresholds (Dietrich & Schulze 2005). As the method of quality control cards combines the use and interpretation of statistical techniques with the implementation in manufacturing processes, is based on international ISO standards and considers different types of data sources, its aspects relevant for this research are identified and integrated in the scoring model. That



different procedures to develop thresholds are necessary becomes clear by comparing e.g. temperature of the storage facility which can be measured directly, and the colouring of a mango, which can normally only be described. Therefore, the alternatives for determining thresholds as used in quality control cards will be illustrated below in the form of a decision tree to cover all possible procedures (Götze 2006).

The next differentiation for quantitative measures in quality control cards depends on the distribution of the basic population and on the unit of interest. Depending on the type of measure, different statistical procedures are used to calculate the mean value of the measure under regular conditions (Dietrich & Schulze 2005). The resulting options for calculating critical thresholds can be found in Figure 6.

**Figure 6: Identifying operation to calculate critical thresholds**

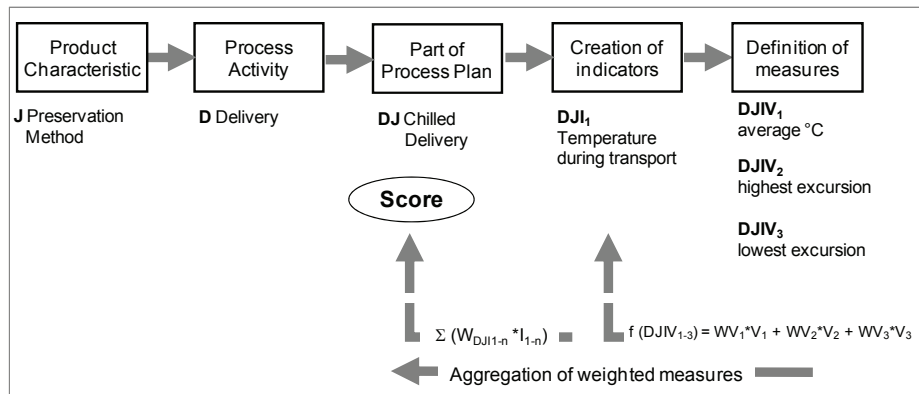


The calculated mean values are starting points for identifying disruptions. Nevertheless, the question rises to what extent deviations have to take place to be critical. Thus, the interpretation of values still needs further assessment. Furthermore, even though disruptions may be identified and measured, they cannot be analyzed in detail, as the measures still have different types of scale. In consequence, obtained values have to be transformed and allocated on one consistent scale. In general, this is possible, if transformation does not lead to misinterpretations (Kromrey 2009). As measures without rank order cannot be transformed easily, wherever possible, these measures should be avoided to enhance the usability of the scoring model. All other scales are transferred into one interval scale, bearing the risk of information losses. However, since the range of potential categories of measures depends on the context the transformation has to cover the entire range of values and to allocate them on one scale, which represents both ends of the continuum of potential values (Eisenführ & Weber 2010). Therewith, all values from different measures can now be compared and put into relation on a single scale.

In a final step, the values are aggregated to identify and evaluate disruptions. Since both, measures and indicators have been constructed so to be independent from others,

multiplying weighted measures with one another would lead to a falsification of results (Kromrey 2009). Therefore, the weighted values of measures are added for each indicator, which are again weighted for each field of the product/process matrix:

**Figure 4: Illustration of the Scoring Model for Disruptions in Food Supply Chains**



Therewith, for each part of the process plan, disruptions are identified by a score larger than zero, while the impact of disruption is assessed based on comparison with the maximum possible score.

#### Conclusion

The scoring model developed in this paper allows for a systematic deduction of performance indicators to identify and assess disruptions in food chains. Therewith, misperceptions can be reduced, weak points identified, and countermeasures prioritized. Furthermore, the analysis of causal relations, systematic errors and efficacy of countermeasures is enhanced. Thereby, robustness of food chains might be increased and disruptions prevented.

By prescribing methodology and decision rules for every step, reliability of measures is increased regarding inter-subjective and inter-temporal measurements. Thereby, transparency of decisions and obtained values is enhanced, reducing discussions and may fasten reaction to deviations. Furthermore, by starting on an abstract level, the applicability of the scoring model to different contexts is increased, whereas quantification of disruptions increases its practical applicability.

However, there are also some limitations to the scoring model. In general, every decision where the scoring model has been tailored increases the risk of incorrect decisions. To be named are for example the choice and specificity of product characteristics to consider, or process attributes, but also the statistical methods to employ. All these decisions bear the risk of alpha and beta errors, which should be considered during the use of the tool. Furthermore, the application of the tool to a specific food chain requires substantial work. Especially at the beginning, when indicators have to be developed, the workload may be significant. However, with increasing experience as well as the potential to use the same indicators again, these efforts may be reduced.

Another important limitation is that the scoring model only depicts the actual situation and relies on data obtained in the past. For instance, the identification of thresholds is obtained from historical stability data. These values may not reflect new developments, such as e.g. the endurance of higher outside temperatures due to more effective cooling. In cases where no stability data exists, reference has to be made to similar cases, which reduces the exactness of thresholds. Even though a prediction of disruptions may be possible for recurring processes, no prediction can be done for highly improbable disruptions. Consequently, the tool needs to be constantly updated and adapted, to assure that it reflects the actual situation.

Further amendments could be done regarding the scope of the tool. For instance, it could be adapted and applied to other industries, with different products and processes. Additionally, empirical evidence may reveal that the degree of specificity and the decision rules have to be adapted. Furthermore, it could be connected to other dimensions of supply chains, such as the structural or institutional focus. Therewith, causal relations between processes and organizational structure could be analyzed. Finally, the ability to predict disruptions could be enhanced, by e.g. connecting the tool to evolution theory and creativity tools.

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## SECTION 5 – INVENTORY AND WAREHOUSE MANAGEMENT

### INVENTORIES MANAGEMENT AND ASYMMETRIC PRICE TRANSMISSION REVISIT: COMMODITY STOCKS

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#### ABSTRACT

This paper simultaneously estimates asymmetric price transmission and asymmetric inventory impacts allowing for switching regimes conditional on underlying market conditions. Our empirical application focuses on the Canadian markets for Wheat and Oilseeds covering two periods of major commodity price spike in 2007/08 and 2010/12. We develop and apply a flexible smooth transition cointegration framework to tests and empirically estimate asymmetries in both price linkage and inventory impacts. The model results confirm the existence of regime-switching behaviour in price transmission and inventory impacts between the markets for Wheat and Canola. Asymmetric impacts of inventories on commodity prices suggest that effective and efficient stock management strategies on detailed market intelligence and application of appropriate econometric techniques. The application of regime-switching techniques provides multiple, useful extension and generalizations of conventional approaches for modelling asymmetric transmissions processes on the degree of market integration and its response to inventory management decisions.

#### 1. Introduction

World food prices increased dramatically in 2007/08, creating spikes in major commodity prices commonly coned the “global food crisis”. During its peak of, the world prices for rice and sugar had increased between 74% and 77%, and the price of wheat more than doubled. Overall, global food prices increased nearly 83% (Revenga 2011). Prices of major food commodities rose sharply again in July 2010, and reached new historic peaks in January 2011, exceeding many price peaks of the of 2007/08 period and have remained well above average price levels ever since then. Moreover, the past global crisis has also highlighted the significance of commodity inventory on market performance. As world grain inventories we found to be at historically low levels in recent years, many experts blamed low inventories as the root cause and trigger of the 2007/08 food crisis (Sampson 2012). Others, however, argued that inventory positively contributes to price increases (Headey and Fan 2008). A third stream of literature propagates that inventory management is strictly independent to market price movements (Dawe 2009). The latter finding support in the fact that during 2010/12 price spike global grain harvests reached near-record levels.

With the issue of global food security filling media headlines and high commodity prices remaining reality, grains inventory management has received renewed attention among economists and policy makers alike. Hence, designing and adopting the most effective and efficient stock management strategies under changing world market environments remains a key issue. While commodity producers, buyers, traders and inventory managers would commonly believe that volatile prices will return to a long-term equilibrium, following a general positive trend in price movements. The 2007/08 and 2010/11 global price spikes, however, have left experts increasingly suspicious of the basic economics of commodity markets. In particular, the crisis has raised new questions and concerns around our understanding of the nature and degree of price co-movements among interrelated commodity markets, as well as seemingly distinct differences in asymmetry price transmission (APT) between bull and bear market periods. Knowledge and understanding of

both market mechanisms remains incomplete. Few empirical studies have investigated the impact of inventory management on price movements beyond descriptive analyses. Existing methodological approaches have been limited to linear/ monotonic models, ignoring critical non-stationary in inventory and market price time series. A reliable quantification of the (supposed) impact of inventory management on non-stationary price movements, allowing flexible (non-monotonic) relationships, requires new analytical techniques.

Motivated by the limitations of existing studies this paper investigates these critical issues by employing new econometric research techniques that enable us to simultaneously quantify the degree of commodity market integration and its interdependency with price shocks in different geographical markets. Both processes are essential to a better understanding of the impact of past price spikes, improved forecasting of price movements and the design of appropriate risk mitigation strategies for inventory management.

## **2. Literature Review**

The analysis of price transmission (market integration, price linkage analysis) explains to what extent product markets are impacted by exogenous shocks and how markets subsequently adjust to return to long-run market equilibrium. The degree of price transmission along vertical supply chains or and between relevant geographical markets have long been considered important indicators of market performance. A rich empirical literature has investigated price transmission in spatially/vertically separated markets. Early studies relied on correlation coefficients and regression techniques, more recent studies have specifically acknowledged the non-stationary of prices. Following the seminal work of Engle and Granger's (1987) many studies jointly model long-run price transmission together with underlying short-run market adjustments. Although extensions to the model of asymmetric price transmission and short-run price adjustments are well developed (Goodwin and Piggott 2001; Sephton 2003; Balcombe, Bailey and Brooks 2007), procedures to empirically test for asymmetric price transmission in the presence of non-stationary long-run price levels are still new (methodology: Park and Phillips 2001; Gonzalo and Pitarakis 2006, application: Gervais 2011).

Although some attempts to investigate the impacts of inventories on prices or price linkages have been made (Wohlgenant 1985, Deaton and Laroque 1992), sound empirical applications are still rare. Abbassi et al. (2012) investigate the role and impact of inventories in explaining the APT in long-run equilibrium. The authors find that the elasticity of price transmission is lower (higher) when inventories are above (below) target levels. While providing evidence of the impact of inventories on APT, the study does not address potential asymmetries in the impact of inventories on market prices. The latter being a vital input into efficient inventory management. For example, assuming a certain threshold market price level exists. Then for prices above the threshold changes in inventory may trigger a negative impact on market price. However, if the market price remains below this threshold, the price-inventory relationship is insignificant. Under this scenario, optimal inventory management would require a detailed understanding of the price-inventory relationship, resulting indifferent strategies under fluctuating market conditions.

## **3. Model**

In this paper we present a model capable of simultaneously estimating the degrees of asymmetries in price transmission and inventories. First, in doing so, we relax the assumption of linear cointegration of prices and allow price transmission and any related impacts of inventor to be regime-switching based on real-world market conditions. Second, we present an empirical application of the framework to estimate APT and ASI in the Canadian markets for Wheat and Canola, both of which underwent significant fluctuations during 2007/08 and 2010/12.

Our empirical strategy is based on the smooth transition cointegration (STC) framework proposed by Saikkonen and Choi (2004). STC allows for greater flexibility in regime-

switching (thus asymmetry) impact analysis, and is considered critical to obtaining reliable estimates of the differential impact of asymmetries between prices and inventories under different market conditions. Our econometric strategy can be decomposed into two steps: 1) Test for linearity vs. STC in price transmission and inventory impacts; and 2) Estimate the preferred regression model. The integrated APT-ASI model based on the STC framework can be specified as:

$$y_t = (\alpha_1 + \beta_1 x_t) + (\alpha_2 + \beta_2 x_t)h(x_t^* - c; \gamma) + z_t, \quad t = 1, 2, \dots, T, \quad (1)$$

where  $y_t$  denotes the dependent variable and  $x_t$  represents a vector of independent variables (potentially non-stationary), and  $z_t$  is a zero-mean stationary error term.  $\alpha_1$  and  $\alpha_2$  are constant terms;  $\beta_1$  and  $\beta_2$  are parameter vectors that measure the elasticity of price transmission and elasticity of inventory impact.  $h(x_t^* - c; \gamma)$  is a smooth transition function (first order logistic function) of the process  $x_t^*$ , with smoothness parameter  $\gamma$  and threshold value  $c$ . In other words the STC can be thought of as a two-regime switching model assuming extreme values of the transition function,  $h(x_t^* - c; \gamma) = 1$  and  $h(x_t^* - c; \gamma) = 0$ , where the transition between regimes is smooth.

#### 4. Data

The analysis applies weekly prices and inventory data for the Canadian Wheat, Feed Wheat, and Canola markets from April 18, 2004 to November 25, 2012, (Canadian Grains Commission 2013). Wheat inventory data includes total inventory of No.1, 2 and 3 C.W. Red Spring Wheat as well as inventory of Feed Wheat qualities at Western terminals and Eastern transfer elevators. Wheat price is the Canadian Wheat Board price quotations for 1 C.W. Red Spring Wheat.

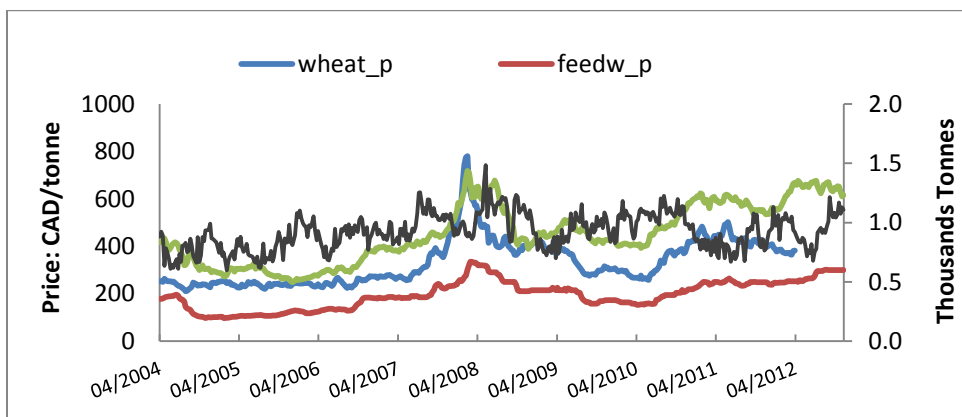


Figure 1. Weekly Canadian Grain Inventory and Prices, 2004-2012

Feed wheat and Canola prices are weekly averages of cash price quotations at the Winnipeg Commodity Exchange reported between April 18, 2004 and July 31, 2009. Subsequent periods use ICE futures market quotes. The available time series is limited to April 2012 when price quotations by the Canadian Wheat Board were discontinued. Figure 1 presents the grain price and stock series used in the analysis.



## 5. Results and Discussion

We begin by assessing the time series properties of the price and inventory series using standard Augmented Dickey-Fuller (ADF) tests (Dickey and Fuller 1979) and KPSS tests proposed by Kwiatkowski, Phillips, Schmidt, and Shin (1992). ADF unit root tests fail to reject the unit root hypothesis for both price and inventory data. The KPSS tests reject the null of stationarity for both data series. And the unit root hypothesis is rejected for both series in first differences, while we are not able to reject stationarity. Hence, the price and inventory series may be considered as  $I(1)$  processes, and the application of STC models seems appropriate.

Regarding the first step of our econometric strategy we test a linear versus STC price transmission and inventory impact model specification. On the basis of non-linear relationship tests we reject the null of linearity in favour of the STC framework for all three selected Canadian commodity markets.

Step two of the identification strategy, estimating APT from the Canola to the Wheat market and ASI on the price of Wheat, equation (2) summarizes the STC estimation results for the Canola-Wheat application.

$$\hat{p}_t^{wheat} = \begin{cases} 1.52 + 0.87 p_t^{canola} - 0.14 stock_{t-1}, & \text{if } h=0 \text{ (when prices are high)} \\ 1.62 + 0.35 p_t^{canola} + 0.28 stock_{t-1}, & \text{if } h=1 \text{ (when prices are low)} \end{cases} \quad (2)$$

$$\text{and } h(p_t^{canola} - c; \gamma) = 1 / \{1 + \exp[-132.57(p_t^{canola} - 6.01)]\}$$

All model coefficients are significant at least at the 0.05 level. Our empirical results confirm the presumed regime-switching behaviour in the linkage between Canadian Wheat and Canola market prices, using the price of Canola as the reference price. The estimated value of the price threshold is 6.01 (logarithmic value in eq. 2), or \$407. When the price of Canola rises above the threshold of \$407/tonne, the elasticity of price transmission between Wheat and Canola price is roughly 0.87. In other words both markets are closely integrated. Interesting both periods of past commodity price spikes, with historic low levels of grain inventories, fall within this regime (Figures 2).

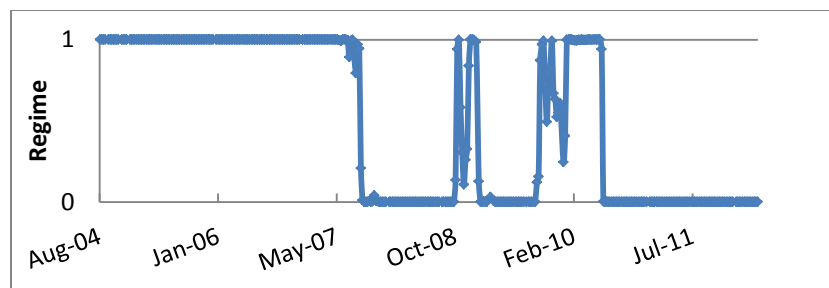
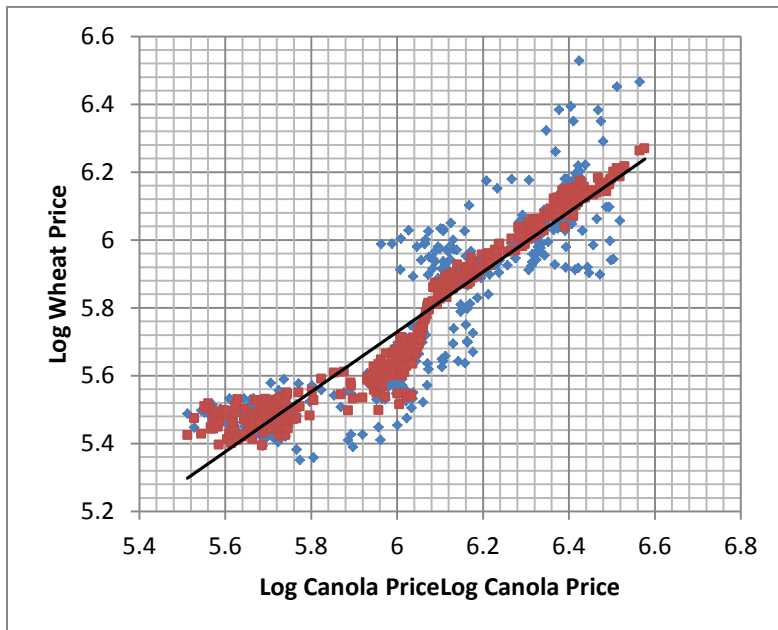


Figure 2. Estimated Regime Function (h) for the Wheat - Canola Case

This result suggests that exogenous market shocks tend to transfer between commodity markets more directly during periods of high commodity price. Meanwhile, we find total grain inventories to have significant and negative impact on commodity prices within the high-price regime. Specifically, a 1% increase in grain inventories translates into a 0.14% decline in the price of Wheat. Although unexpected at first sight, this finding may provide some justification for that fact that a few wheat market players (Ukraine, China) continued to increase grain inventories even during past periods of rising wheat price (including spikes). However, the strategy of utilizing inventory to control the domestic market price might be neither efficient nor effective, as its impact (as measured by the elasticity of price to inventory) is small (50%).

In comparison, when the price of Canola is relatively lower, below the threshold level of \$407/tonne, the market relationship the two commodities switches into another regime (Regime 1, Figure 2). The elasticity of price transmission drops from 0.87 to 0.35, indicating a loosening of the linkage between both commodity markets during periods of lower commodity prices. Furthermore, and in contrast to the regime found under higher commodity price, inventory levels are found to be positively linked to the commodity price. An increase in Wheat inventory of 1% causes the price of Wheat to increase by 0.28%, an inelastic yet significant upward movement. This finding provides support for the long-term observation that under normal world market condition of consistently downward trending Wheat prices, building/increasing inventory is an efficient and effective strategy to counter downward price pressured in the international market.



Note: Blue dots are the original data points, the black line indicates a linear trend, and red dots are indicate fitted values from the STC models.

Figure 3. STC Model Fit for the Wheat - Canola Case

Beyond the scope of this analysis, the results of a STC model analysis similar to the one presented in this paper could be used for a simple benefit-cost analysis of inventory management and forecasting of market price movements. The estimated ATC and ASI presented in Figures 3 give a good indication of the model fit of the STC model specification.

## 6. Implications and Conclusions

In this paper we employed a flexible smooth transition cointegration (STC) framework to empirically estimate the degree of price linkage and impact of variations in commodity inventories in the Canadian commodity grain and oilseed markets. Under the explicit consideration of regime-switching in the adjustment processes after exogenous market shocks we find significant evidence of asymmetric price transmission and asymmetric impacts of changing inventories in relationship between the Canadian Wheat and Canola markets. Estimated APT and ASI elasticities vary significantly conditional of observed world market price levels.

Generally speaking, during periods of relatively low commodity prices (below threshold levels), Canadian Wheat and Oilseed markets appear to be less integrated, while grain inventories have a positive impact on price of Wheat. In contrast, during periods of higher commodity prices (prices exceeding threshold levels) market integration improves significantly, while at the same time, the impact of inventories on grain price reverses to be negative and of smaller magnitude. The results on asymmetric stock impact (ASI) clearly indicate that effective inventory management and long-term inventory strategies rely on detailed market intelligence and application of appropriate econometric techniques.

However, our finding should not be interpreted as evidence that grain inventory has the ability to depress domestic market prices during periods of otherwise high commodity prices. The findings present here should serve as a 'big picture', which suggests that increasing inventory levels in defined geographical markets have the ability to send signals to market participants which ultimately results in a negative price adjustment. A generally negative impact of inventory on commodity prices during periods of price spikes may reflect its risk-alleviating effect for consumers. That said, increasing commodity inventories during such period may alternatively reduce uncertainties associated with the perceived availability of "sufficient food" from the consumers' view. This in turn might result in a minor reduction in market prices.

Overall, the analysis presented in this paper, and the application of Canadian data is limited by the exclusion of specific information regarding the influences of government regulations, especially the presence and market intervention by the Canadian Wheat Board. Further investigation and explicit consideration of the commodity demand and supply factors, and more detailed data on the nature and extend of policy interventions and their underlying institutional structure would be helpful to the better understanding of the effects of grain commodity inventories and inventory managements on market performance.

Finally, the contribution of this paper lies predominantly in promoting a methodological framework which to date has seen little empirical application in the context of analysing the impact of 'market conditions' on price transmission and the impact of commodity inventories. Especially the application of (multiple) regime-switching techniques allows researchers to obtain valuable information on the degree of market integration and its response to inventory management decisions. Moreover, while regime-switching in price and inventory impacts can result from other factors, such as policy interventions, market power, and/or asymmetric information, the approach presented in this paper provides a useful extension and generalization of conventional approaches for modelling asymmetric transmissions processes.

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# **ANALYSIS OF INVENTORY POLICIES FOR A STOCHASTIC PERTURBED DEMAND MODEL**

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## **INTRODUCTION**

The effects of stock-outs are clearly a loss of an immediate sale and also a loss of goodwill which in turn leads to a potential loss of some future sales. The most commonly used method for quantifying the impact of stock-outs is to impose a penalty cost on stocked-out items. However, finding an appropriate penalty cost can be challenging because the potential loss of future demand is difficult to estimate. As an alternative to the penalty cost models, a so-called perturbed demand model can be used, where lost sales result in altered future demand. This is a more direct way of modelling the effects of stock-outs and is a more realistic representation of the actual consumer behaviour.

We develop here a periodic-review inventory model with stochastic perturbed demand. We assume the demand is non-seasonal, stock-outs result in lost sales, no fixed order cost, and orders arrive after some given lead time. We show that under these assumptions, a base-stock policy is optimal where the order up to level is dependent on the demand deflation factor which is calculated as a function of stock-outs in current as well as past periods. We formulate the model as a Markov Decision Process. Then, an approximation is developed to relate our model back to the penalty cost setting.

## **LITERATURE REVIEW**

The US and European retail industry is dependent on manufacturing from other countries. While the labour is cheaper, the downside is increased lead time for order fulfillment. This paper is concerned with extending applicability of perturbed demand models to include non-instantaneous lead time. Perturbed demand models are a class of inventory models where stock-outs result in a loss of future demand. Similar to penalty cost models lead time is modelled using an added dimension in the state space. Lost sales models with penalty costs do not have simple optimal order policy structures like their backorder equivalents (Arrow et al., 1958). The resulting order policy is not easily characterized. Perturbed demand models have an even more complex ordering policy due to the dependency of the order level on the current level of demand deflation.

A traditional lost sales penalty cost model with positive resupply lead time was first introduced by Arrow, Karlin and Scarf (1958). The optimal order policy does not take on a traditional base stock policy structure. Instead it has a constant order level for low on hand inventory levels then as inventory increases the order quantity starts to decrease. While the

structure may not be the same, the policy still converges to a steady state policy in the long run (Iglehart, 1963).

Our model assumes perturbed demand, first formulated by Schwartz (1966, 1970), in which future demand is altered by stock-outs. Other models where demand is affected by ordering decisions include those by Hill (1976), Ernst and Powell (1995), and Diana and Petruzzi (2001). However, only Robinson (1990) uses the actual number of disappointed customers to modify the underlying demand distribution seen by a retailer. In contrast, our underlying demand distribution is stationary but is modified by a scalar whose value is based on the stock-out history and on two consumer behaviour parameters.

Due to the complexity of the single period lead time optimal policy, many approximations have been developed to solve lost sales penalty cost models. Zipkin (2008b) provides an overview of these approximations. One common assumption is that the policy takes on a base stock structure because it is easy to implement. The total cost function for the penalty cost setting is convex in the base stock level  $S$ , making the search for the base stock level relatively simple (Janakiraman and Roundy 2004). The literature suggests that lost sales models with penalty costs have complex ordering policies that can easily be approximated by simpler base stock policies without a large increase in cost. For example, Huh et al. (2009) proves that as the penalty cost grows large in relation to other costs, a base stock policy asymptotically approaches the optimal solution. Morton (1971) creates a myopic critical fractile procedure that works well for short lead times.

In Lavin (2013), it is shown that the optimal order policy for a perturbed demand model with instantaneous arrivals is base stock with a different base stock for each demand deflation level. Other perturbed demand models have made the same assumption about instantaneous order arrival (Schwartz 1966, 1970, Robinson 1990 and Ernst, Powell 1995). In this paper, we add a lead time to the order, develop a solution approach to this problem, and compare the results to those of traditional penalty cost models.

## MODEL FORMULATION

Consider a stochastic-demand, periodic-review model with perturbed demand—i.e., demand deflation as a result of lost sales—as an alternative to imposing a penalty cost for lost sales. We assume that in the absence of stock-outs, the demand each period follows a stationary cumulative distribution  $G(\xi)$ , which we refer to as the *underlying demand distribution*. However, the consumer behaviour literature has demonstrated empirically (Campo et al. 2004; Verbeke et al. 1998) that stock-outs affect the immediate future demand—meaning that some customers “abandon” on this product and/or retailer while others will return to purchase at a later date. Consistent with other perturbed demand work, we employ a *demand deflation factor*  $\alpha_n$ , where  $n$  denotes the current period. This factor is computed based on the level of demand lost in periods prior to period  $n$ . The timeline of events is shown in figure 1. At the start of the period, we evaluate the current state of the system, defined as the current on-hand inventory ( $x_n$ ) and the demand deflation factor from the previous period ( $a_n$ ). Based on the state values, an order is made for  $z_n$  units, and the materials cost is imposed at the time the order is placed. Next, demand occurs for the period. Then holding cost and revenue are calculated based on the inventory remaining on-hand after fulfilling demand. Last, the order due to be delivered this period arrives. Similar to Bellman’s (1955) formulation, orders are assumed to arrive at the end of the period after holding cost is assessed—and in our case, after demand deflation is calculated as well—in order to eliminate the need for an extra state dimension. (Note: here, we assume that lead time is constant and equal to one; orders are made at the start of the period and arrive at

the end of the period, however the model is flexible and can easily accommodate longer lead times.)

Demand deflation in period  $n$  is based on actual demand fulfillment performance in period  $n-1$ ; therefore,  $\alpha_n$  is computed at the start of  $n$ , before demand occurs. The actual demand in period  $n$  is given by  $\alpha_n \xi_n$  where  $\xi_n$  represents the realized sample from the demand distribution  $G(\xi)$ . Thus, if the expected underlying demand is  $\mu = \int (1-G(\xi))d\xi$ , the expected realized demand is  $\alpha_n \mu$  given demand deflation factor is  $\alpha_n$ .

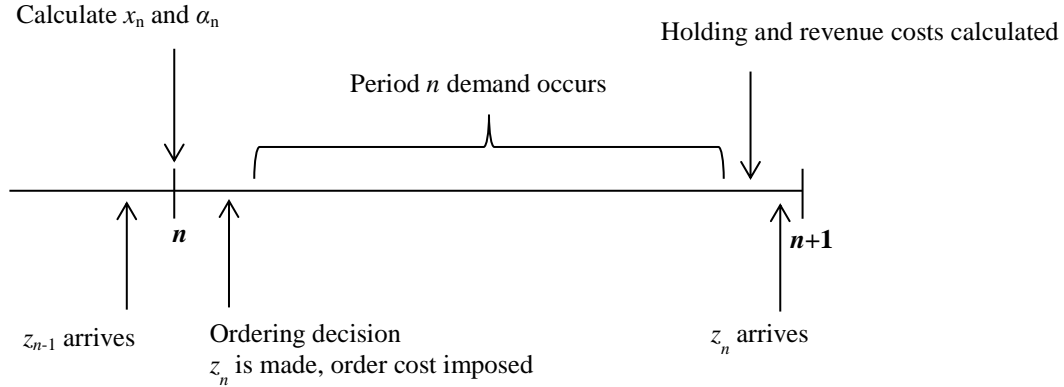


Figure 1: Timeline of events for lead time one case

While  $\alpha_n$  is influenced by prior lost sales, this effect may be attenuated by other aspects of consumer behaviour. These aspects are the persistence of their memory of past stock-outs and the possibility that some customers are willing to effectively “shrug off” a stock-out such that it does not affect their likelihood of future purchase. While the specific effect on demand has not been directly studied in the literature, we capture presumed consumer behaviour in two model parameters:  $\beta$ , which we call the *deflation intensity*, reflecting the strength of the effect of stock-outs on future demand; and  $\lambda$ , which we call the *deflation persistence*, reflecting how long past stock-outs continue to affect future demand. Schwartz (1966) suggested that the effect of past disappointment will decline exponentially over time. Similarly, our demand deflation value in period  $n+1$  depends on the incoming demand deflation factor ( $\alpha_n$ ); the realized sample from the demand distribution in period  $n$  ( $\xi_n$ ); and the available inventory on-hand at the start of period  $n$  ( $x_n$ ), as follows:

$$\alpha_{n+1} = T_\alpha(\alpha_n, \xi_n, x_n) = \begin{cases} \lambda + (1-\lambda)\alpha_n & x_n \geq \alpha_n \xi_n \\ \lambda \left( 1 - \frac{(\alpha_n \xi_n - x_n)\beta}{\alpha_n \xi_n} \right) + (1-\lambda)\alpha_n & x_n < \alpha_n \xi_n. \end{cases} \quad (1)$$

Expression (1) shows that if there was no demand lost in the prior period ( $n$ ) (top portion of the bracket in (1)),  $\alpha_{n+1}$  is computed by smoothing it with  $\alpha_n$ , reflecting the “deflation persistence” from previous periods. Thus, if the persistence factor  $\lambda$ , is close to 1, the effect of previous losses will dissipate rapidly, whereas if it is close to 0, previous demand fulfillment performance will dominate the current performance. Also, from expression (1), if there was lost demand in the prior period (bottom portion of the bracket), the first term

includes the deflation intensity ( $\beta$ ) effect. The impact of lost sales from the previous period ( $\alpha_n \xi_n - x_n$ ) on future sales through  $\alpha_{n+1}$  is attenuated by a multiple of  $\beta$ .

Note that the demand deflation factor is bounded between zero and one. This implies that demand cannot be negative, nor can it exceed the upper limit of the underlying demand distribution. It is assumed that the demand deflation is constant throughout a given period, thus stock-outs within the period will not deflate demand in that period. Underlying demand is assumed to be stationary over time, but demand deflation, and consequently the realized demand, is dependent on past events.

A unit holding cost,  $h$ , is incurred for each item on-hand after demand occurs. For each unit sold, revenue  $r$  is received. Revenue is modelled as a negative cost since the model is a standard cost minimization problem. The demand distribution has an underlying cdf  $G(\xi)$ , which is scaled by current demand deflation. Then, the immediate (one period) net cost given  $y$  units on-hand and demand deflation factor  $\alpha$ ,  $L(y|\alpha)$ , is

$$L(y|\alpha) = \int_0^{\frac{y}{\alpha}} h(y - \alpha\xi) g(\xi) d\xi - \int_0^{\frac{y}{\alpha}} r\alpha\xi g(\xi) d\xi - ry \left( 1 - G\left(\frac{y}{\alpha}\right) \right).$$

Assuming unit materials cost  $c$  ( $c < r$ ) and given  $x_n$  units in inventory with demand deflation factor  $\alpha_n$  and discount factor  $\omega$  ( $0 \leq \omega \leq 1$ ), the total horizon cost at period  $n$  is a recursive expression,

$$f_n(x_n, \alpha_n) = \min_{z_n > 0} \left\{ cz_n + L(x_n | \alpha_n) + \omega \int_0^{\infty} f_{n+1} \left( (x_n - \alpha_n \xi)^+ + z_n, \alpha_{n+1} \right) dG(\xi) \right\}, \quad (2)$$

Additional lead time can be included in the cost function with a few changes.

## CALCULATION OF THE OPTIMAL POLICY

The model is formulated as a Markov decision process (MDP) and the optimal policy determined using the value iteration method (Howard, 1960). Since the demand deflation factor  $a$  appears in the discrete-valued state space of the MDP formulation, this continuous value must be expressed as a discrete value, which requires rounding its value using a specified rule. Using a uniform grid to approximate continuous variables is commonly done due to the simplicity this affords in solving stochastic control problems (Chow and Tsitsiklis 1988). Increasing the number of discrete intervals used to approximate  $a$  results in a more realistic representation of the problem. The realism, however, comes at the cost of a larger state space, resulting in a longer solution time. Another argument for discretizing the demand deflation factor is that the retailer may actually not know the demand deflation factor with exact precision and would need to estimate it anyway.

The discretization of the demand deflation factor has an undesirable consequence, which is that it may contribute to the stochastic process no longer being ergodic. While the process is guaranteed to be ergodic if  $\lambda > 0.5$  (as shown in Lavin, 2013 for the zero lead time case), for problems with smaller  $\lambda$  values (those for which the effects of previous demand losses are more persistent), it is possible that, once a significant reduction in the value of  $\alpha_n$  occurs, realized demand may get "stuck" at a level persistently below its desired value. Larger gaps between the discrete values of  $a$  can exacerbate this effect; therefore, a more finely specified  $a$  lessens the likelihood of the non-ergodicity. We assume that the demand



deflation factor has an initial value of one, a sensible starting point for the start of the horizon since no demand is lost yet.

The optimal solution can be computationally difficult to calculate because of the large state space. The optimal policy is dependent on both dimensions of the state space with a one-period lead time. Computationally the value iteration method must be applied until the gain for each state converges. We stop value iterations when the following conditions are met: the sum of the absolute change in gain for all periods is less than some specified value, and none of the decisions have changed across periods. These conditions may take several iterations to converge, depending on the value of  $\lambda$ , the weight put on the most recent period. High  $\lambda$  values solve quickly, but when  $\lambda$  is low, the demand deflation factor tends to change slowly from period to period, meaning that a larger number of iterations are needed for the state probabilities to converge.

Penalty cost models with lost sales do not always have nicely defined optimal order policies. While the backorder case results in a base-stock policy, the optimal policy of a lost-sales model does not take on an easily characterized policy structure (Nahmias, 1979). Similarly, when demand is perturbed as a result of stock-outs, the optimal order quantity is a function of the state the system expects to be in when the order arrives. The order made in period  $n$  is used to fulfill customer demand in period  $n+1$  (and beyond). We demonstrate below that the optimal order quantity may increase, level off, then decrease as a function of the beginning-of-period inventory as seen in figure 2. The figure was generated from solving the optimal policy for eight problems. The cost and demand distribution were held constant at  $c = 1$ ,  $r = 1.5$ ,  $h = 0.2$  and the demand was negative binomial (20, 0.5). The demand sensitivity parameters were varied with four levels of  $\lambda = \{0.35, 0.5, 0.75, 1\}$  and two levels of  $\beta = \{0.25, 1\}$ . When on-hand inventory is low, then stock-outs will likely occur, lowering demand in the future. This reduces the amount ordered because when the order arrives demand will have already been lowered. The optimal order quantity increases as the on-hand inventory increases because fewer stock-outs are expected, resulting in less demand deflation. The order quantity continues to increase until ordering more units yields little or no improvement in expected demand deflation to start the next period. When on-hand inventory is large, inventory will be carried over to the next period; thus the order quantity can decrease because some units will already be available when the order arrives. As the inventory on hand increases, the policy tends take on a base stock policy structure.

The steepness of the optimal order quantity increase, for the low inventory section of the policy, is dependent on the demand sensitivity parameters.

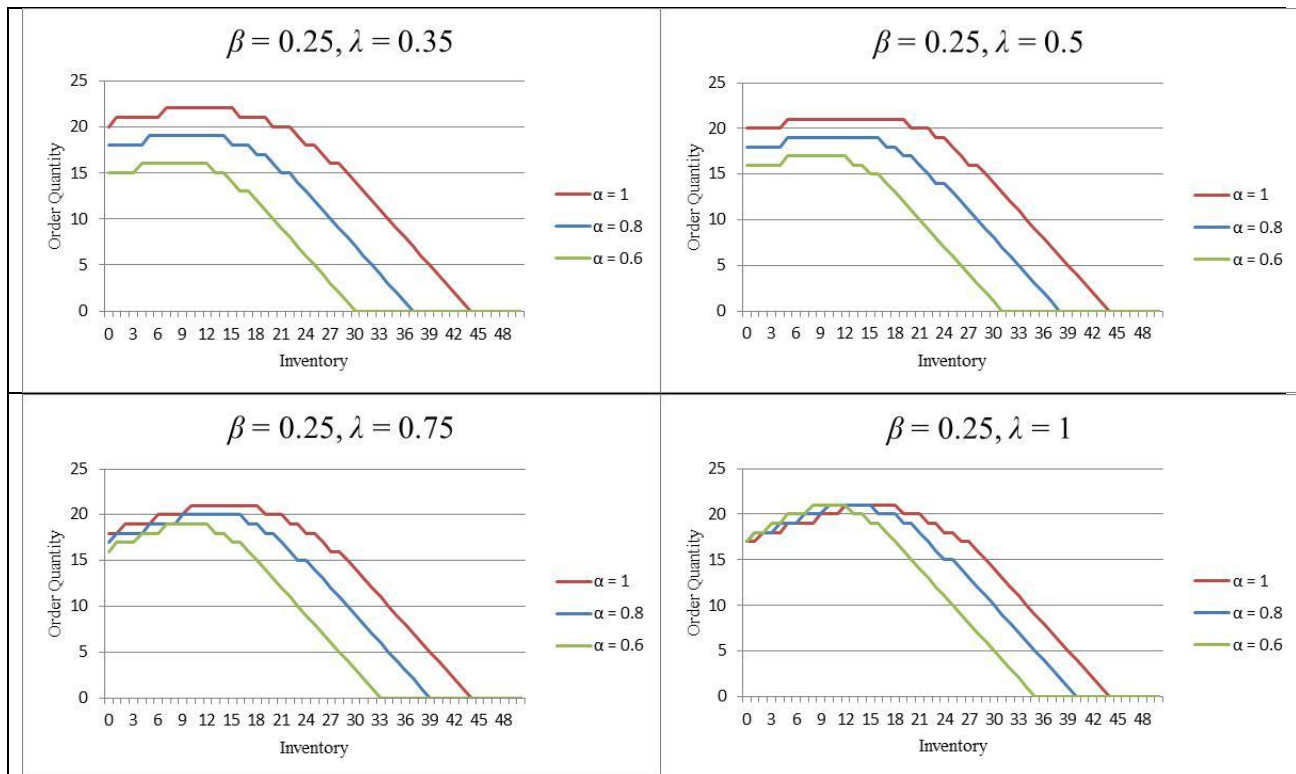
Figure 2 shows the optimal policy for eight different combinations of  $\beta$  and  $\lambda$ . The high inventory side of the policy seems to be largely unchanged as a function of the sensitivity parameters. The low inventory side is highly dependent on the sensitivity parameters. As  $\beta$  increases, there is a sharp drop in the low inventory order quantity. High  $\beta$  cases will have a dramatic shift in demand deflation if stock-outs occur, and stock-outs will likely occur when inventory on-hand is low, reducing future demand.

## **IMPLIED PENALTY COST AS A FUNCTION OF LEAD TIME**

Here we use Morton's (1971) approximation to estimate a penalty cost for various lead times. Morton uses a pair of values  $z$  and  $S$  to define the heuristic policy. The same set of problems is used to determine the best penalty cost policy for different lead times. We notice that the order policy changes as a function of lead time. Lavin (2013) shows how to use the Morton approximation to calculate an implied penalty cost. This procedure helps to determine if lead time influences the penalty cost.

The Morton heuristic structure allows an implied penalty cost to be determined. Enumerating all the penalty cost policies, it is possible to determine the best penalty cost to use. The Morton (1971) heuristic has been shown to perform increasingly poorly for longer lead times (Zipkin, 2008), but it is one of the few ways to relate the perturbed demand model to a lost sales penalty cost model. One alternative would be to use a base stock approximation, however it has been shown to be a bad approximation for the lost sales model when lead time is long and penalty cost is low compared to holding cost (Zipkin, 2008; Hue et al. 2009).

Thirty six problems are solved for the best Morton penalty cost policy for three cases: instantaneous, one-period, and two-period lead times. The gain for each policy and problem instance is calculated within an MP setting. To keep the state space manageable for the lead time two case, the mean demand was reduced to 5 from 20 and  $\Delta$  was increased to 0.05 from 0.005. The test set consists of the following values:  $c = 1$ ;  $r = \{1.5, 2\}$ ;  $h = \{0.05, 0.2, 0.4\}$ ;  $\beta = \{0.25, 0.5, 1\}$ ; and  $\lambda = \{0.75, 1\}$ , with demand being negative binomial (5, 0.5). The average penalty cost across the 36 test cases was taken for each lead time instance.



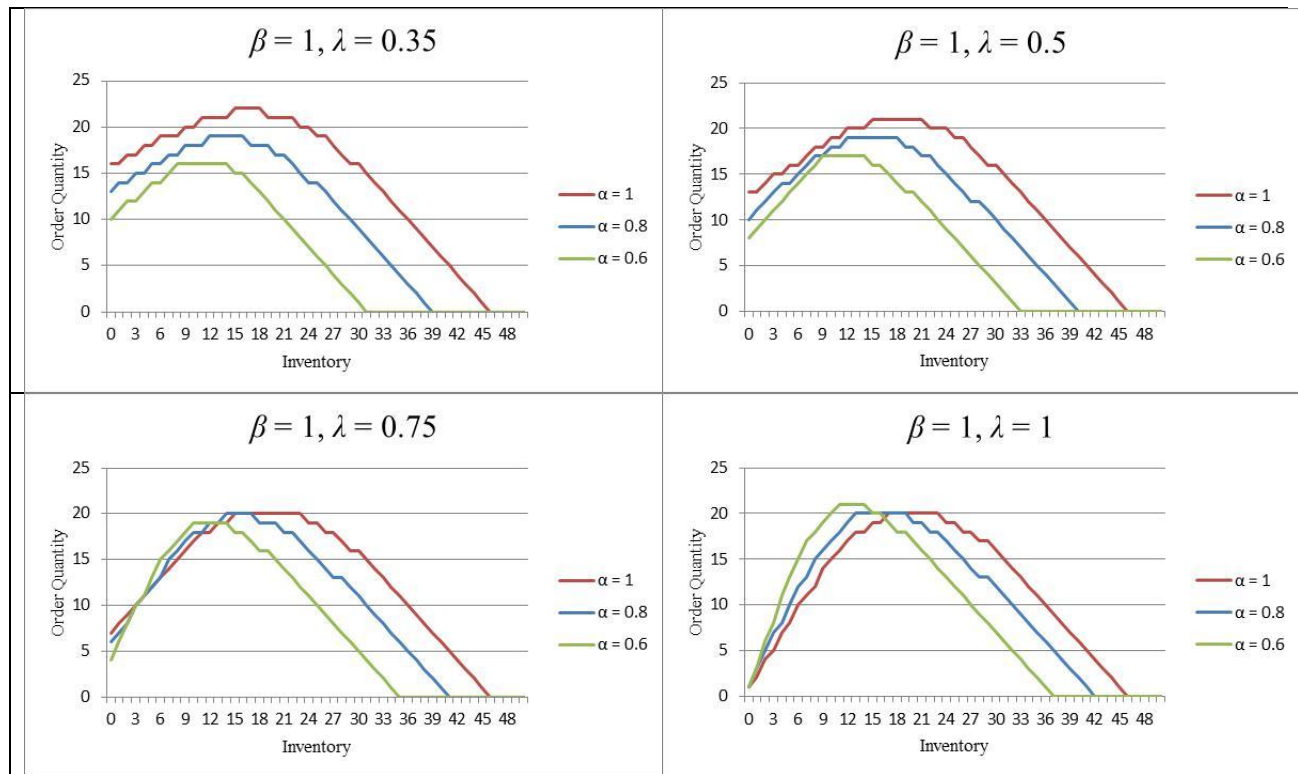


Figure 2: Optimal policy example Neg. Binomial(20, 0.5),  $c = 1$ ,  $r = 1.5$ ,  $h = 0.2$

Figure 3 demonstrates how average best penalty cost decreases as lead time increases. There is a significant drop from lead time one to lead time two, and it even dips below the revenue term value. As the lead time increases from one period to two the  $z$  value in the policy consistently drops (29 of 36 problems) while the  $S$  value consistently increases (36 of 36 problems), from best policy. The increase in  $S$  even with a decrease in  $n$  is due to the convolution of an additional period of demand. The decrease in  $z$  and increase in  $S$  make the policy have a longer flat section, meaning that the order quantity is a fixed level longer instead of having a base-stock structure. Using a Markov Process to evaluate policies becomes impractical for problems with lead times of greater than three periods. The trend is to have a lower penalty cost as the lead time increases. The decreasing trend holds for all problem parameter subgroups. There are several possible explanations of this occurrence. One is that longer lead times result in a worse service level, thereby lowering the demand deflation so fewer orders are needed. There is a drop in demand deflation, but it is not enough to account for the significant drop in penalty cost. The second is that we are pooling risk as more periods are convolved in the calculation of  $\tilde{S}$ . The two fractiles are the same, so lowering the needed fractile in  $S$  also lowers the  $\tilde{z}$  fractile, resulting in a lower implied penalty cost as lead time increases.

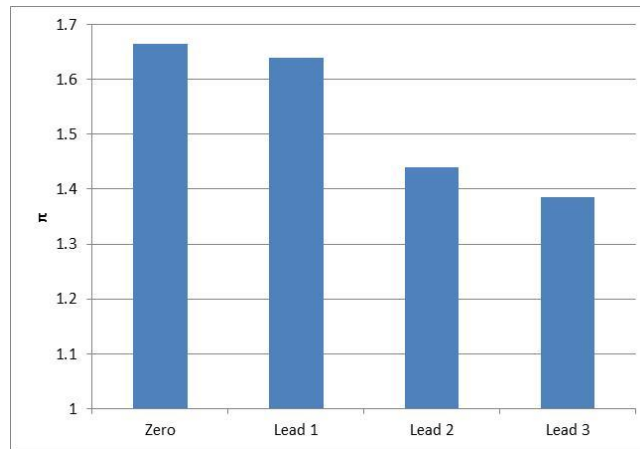


Figure 3: Approximate penalty cost ( $\pi$ ) as a function of lead time

## CONCLUSION

For periodic review of perturbed demand models with non-zero lead time, the optimal policy has a non-standard structure. Orders are based on expected state of the system when the order arrives, factoring in both inventory and demand deflation values. As lead time grows, there is more uncertainty in the future state of the system when the order arrives. The optimal policy is approximately base stock for a large on-hand inventory. An approximate policy structure can be found using the approach of Morton (1971). It was possible to use this policy to find an implied penalty cost. With the increase in lead time we see a decrease in the average implied penalty cost. While most penalty cost models assume that the penalty cost is not dependent on lead time, we show that lead time does, indeed, have an effect on the penalty cost. Longer lead times do not allow the decision maker to adapt to changes in demand deflation as fast as the instantaneous order arrival case because units are not available to satisfy demand as quickly.

The difference in policy structure between penalty cost and perturbed demand models with lead times is a significant finding. The penalty cost models assume that stock-outs do not have a direct correlation to loss of demand; consequently, the optimal policy structure is flat and then decreases. Perturbed demand models, on the other hand, assume that stock-outs alter demand: when stock-outs occur demand decreases in the next period, which is reflected in order policy.

## ACKNOWLEDGEMENTS

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# **SERVICE PARTS INVENTORY MANAGEMENT WITH SPACE AND BUDGET LIMITATIONS: REPAIR KIT DIMENSIONING**

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## **1. Introduction**

An effective and efficient service parts management is critical to achieve customer satisfaction and increase profitability. It determines the respect of Service Level Agreements in the short term and leads to customer retention in the long term, thus constituting a critical success factor for companies supporting an installed base.

Recently the importance of after sales services strongly grow, as confirmed by many author in literature.

In 2005, McKinsey reported that aftermarket part supply business is around \$400 billion US dollars (Gallagher et al., 2005). In 2006, the SAS institute estimated that approximately 8% of the gross national product of the United States is tied up in aftermarket spare parts and repair services (SAS, 2006). Blumberg estimated that the compound annual growth rate of after sales services is 14.9% in the United States and 15.8% worldwide (Amini et al., 2005).

When companies offer on-site repair services, their technicians take a set of service parts in their cars or vans for their daily tour, although they do not know which parts will be actually required to carry out the repair interventions. The inventory decisions about which service parts to take to the repair site(s) and in what quantities is called the repair kit problem - RKP (Bijvank et al., 2010). Since the size of the warehouse (car or van) is very limited, it is very important to select the suitable parts to put on stock and identify the best suited inventory replenishment policy, in order to minimize costs (included returns to customers).

The main objectives of this paper are: 1) to identify, analyze and compare research about RKP: we will propose a classification of the literature based on several criteria, among which the proposed solution to the problem and the applicability to real contexts; 2) moving from the evidence of literature review, to identify the guidelines for developing a general model, easy implementable by company managers and practitioners, that allow to dimension travelling warehouses under budget constraints. This model should consider the main aims and constraints in real conditions.

Our paper could be divided into sections: Section 2 describes the methodology, in Section 3 we show the findings from the literature analysis and finally in Section 4 we discuss the implications of the research and future research directions.

## **2. Methodology**

Even if general literature about spare and service parts is quite large, few papers focus on the repair kit problem and they propose different approaches to dimension engineers' vans. First papers about this topic are dated at 1970s, while during the last decade new contributions have been produced.

From a modeling point of view, the repair kit problem could be considered similar to the knapsack problem; this is the reason because many papers, especially the older ones, focus

on the research of optimal or sub-optimal solutions by the adoption of linear programming or heuristic methods.

From a company point of view RKP corresponds to the choices about which parts carry to the customers for reparation and the respective quantities. They involve all the service parts management and logistic distribution processes and encompass many activities, that are listed below;

- Inventory management strategy definition: the choices about replenishment policy and replenishment frequency affect average stock levels for each SKU allocated and they consequently affect SKUs allocation (under budget or space constraint).
- SKUs allocation: it consists in selecting which part to dedicate to the kit. According to the substantial differences among spare parts allocation could be associated to service parts classification (Bacchetti and Sacconi, 2012).
- Replenishment policy definition: it is a consequence of the inventory management strategy definition and consists in setting the suitable (best performance) parameters' values.

Moving into this framework, the first activity of our literature review consisted in identifying relevant papers about RKP. The research has been conducted by the identification of keywords: repair kit problem, service parts, service level, constraints. We identified 9 papers.

Since RKP could be conceived as a warehouse with strong space constraints and/or budget ones, we included in our literature review also papers not specific for RKP dealing with service parts management in presence of constraints.

### 3. Findings

In analyzing literature we carried out a classification, based on selected criteria.

Firstly it is interesting to identify the papers that discuss the specific problem of vans or travelling warehouses dimensioning and others that develop or adopt elements/models useful in RKP. For the 9 papers focused on RKP, Table 1 describes the main papers' aims; we classified the scopes into 4 categories and we could observe that many papers develop new policies (or heuristic solutions) for the RKP. This is reasonable considering the few literature contributions on this topic.

We also categorized papers according to the proposed approach to the repair kit problem solution into two classes.

- Some papers, that we define as *One-step-approach* ones, consider all the possible items to insert in repair kit and, by evaluating the performances of each combination (usually by heuristics quite easy to implement), identify the suitable set of components.
- Other papers, moving from the basic idea of knapsack problem, try to associate to each component a parameter that quantifies its contribution to function objective (FO); then the rank of service parts based on this parameter allows to identify the sequence of components for allocation to repair kit. These papers allocate SKUs starting from the one with highest contribution to FO, to fulfill the constraint (space or budget). We classified these papers as *Two-steps-approach* ones, because they make a conceptual separation between the choices about *what* and *which quantities* to put in repair kit.

Reference <sup>1</sup>	Scope category				Approach	
	Developing a new policy from first principles	Fine-tuning or adjusting an existing policy into the spare/service parts context	Implementing a policy into a real/empirical or theoretically generated environment	Comparing existing and/or new policies and obtaining insights	1 step	2 steps
[1]	X				X	
[2]			X		X	
[3]		X				X
[4]		X				X
[5]			X		X	
[6]	X				X	
[7]				X	X	
[8]	X				X	
[9]	X				X	

Table 1 – Aim and approach description of analyzed papers

Table 2 proposes a comparison among the different contexts of the considered papers. In particular it is interesting, in order to evaluate the proposed solution about inventory policies, to know demand patterns, parts proposed classification and timeline (single vs. multi period). Timeline is an essential element in RKP because it determines the possibility of restocking vans among visiting consecutive customers: single period papers assume the possibility of restocking after each visit, but in real conditions this is often not a realistic hypothesis.

Reference	Supply chain context	Timeline	Demand pattern		Part classification
	Single vs. Multiple echelon	Single vs. Multiple period	Type of demand	Deterministic vs. Stochastic	
[1]	Single	Single	Failures of parts on a given job are not necessarily independent	Non explicit	Not considered

<sup>1</sup> See References paragraph



[2]	Single	Multiple	Failures of parts are stochastically independent	Stochastic	Considered (Components' criticality: functional, aesthetic)
[3]	Single	Multiple	Failures of parts are stochastically independent	Stochastic	Not considered
[4]	Single	Multiple	Demands are not perfectly dependent for any pair of part types	Stochastic	Not considered
[5]	Multiple (emergency channel)	Multiple	Demand processes for different kit types are independent and demand for kit occurs according to a Poisson process	Stochastic	Not considered
[6]	Multiple (2-echelon)	Single	Failures of parts are stochastically independent	Stochastic	Not considered
[7]	Single	Single	Failures of parts are stochastically independent	Stochastic	Not considered
[8]	Multiple	Multiple	Not specified	Deterministic	Not considered
[9]	Single	Single	Failures of parts are stochastically independent	Stochastic	Not considered

Table 2 – Paper description: supply chain context and demand pattern

Despite of the importance of service parts classification (Bacchetti and Sacconi, 2012; Bacchetti et al., 2013), increased by constraints of travelling warehouses, only one among the examined paper alludes to classification in the proposed model.

As previously said, from the modeling point of view RKP could be considered as a sort of knapsack problem. Contrary to knapsack problem the objective function (FO) consists of the overall cost minimization. In all the considered papers the FO structure is the same and consists in cost minimization. In replenishment process companies incur costs (logistic or not) due to service parts management. The main cost elements are: 1) inventory holding, 2) ordering, picking and packaging, 3) delivery or transportation, 4) stockout (due to return to customer or penalties), 5) parts obsolescence. From the mathematic point of view to model these costs in a function objective is not easy, because they depend on different parameters. In particular *inventory holding cost* depends on average stock levels; *ordering, picking and packaging costs* depend on number of orders (orders can group different parts required in one job or daily tour); *delivery and transportation costs* could depend on many factors, such as distance, quantities, criticality, LTs; *stockout (or shortage) cost* could present fixed component (return to customer) and variable ones, subject to downtime or failure criticality; finally *obsolescence cost* is usually related to no-moving time.

It is interesting to evaluate that the selected papers consider only inventory holding and stockout costs; no paper consider the other ones, except Teunter et al. (2002) that hint at a purchase cost (a sort of ordering cost).

Reference	Objective function	Costs			Constraints	Constraint description	Model class	
		Inventory	Stockout	Others			Cost model	Service model
[1]	Cost minimization	X	X		Yes, single	Number of parts	X	
[2]		X			Yes, multi	Service level, storage space, number of parts of each type		X
[3]		X	X		Yes, single	Service level	X	X
[4]		X	X		Yes, single	Service level	X	X
[5]		X			Yes, single	Service level (in terms of kit-readiness)		X
[6]		X	X	Purchase, Disposal	No		X	
[7]		X	X		Yes, single	Service level (in terms of job completion rate)	X	X
[8]		X	X		Yes, single	Capital budget, service level	X	X
[9]		X	X		No		X	

Table 3 – Model description: costs and constraints

Furthermore it is interesting to distinguish between cost and service models. In a cost model the sum of the expected holding and stockout costs is minimized, whereas in a service model the holding costs are minimized subject to a service level constraint (Bijvank et al. 2010). In particular two of the examined papers propose both cost and service models.

Finally, in order to complete the description of repair kit management process, it is interesting to evaluate the replenishment policy that the considered papers propose for restock kits.

Literature about service parts (in general context, not specific for repair kit), usually suggests periodic inventory policies, (T,S), (s, S) or (S-1, S). All the examined paper for RKP propose a periodic (T S) policy. This result could be related to set of evaluated cost: Bijvank (2009), indeed, asserts that in presence of ordering cost (s, S) policy performs better than (T, S), so minimizing cost not considering ordering costs could suggest to adopt (T, S) policy.

In the next paragraphs we will describe the milestone papers about RKP.

Mamer et al., 1982, moving from Balinsky problem's solution propose a mathematical model and calculate the number of computational steps for the max flow algorithm in the worst

case. This is one of the older literature contribution and is not easy to put in practice from managerial point of view in companies.

Heeremans and Gelders (1994) study the determination of the optimal kit of parts and tools solving the trade-off between annual holding costs and customer service levels. The problem focuses on

- shortages: they involve higher number of second visits to customers (to complete repair services), lower customer service levels and higher service costs
- holding costs due to the set of parts and tools stocked
- space constraint imposed by the use of a vehicle.

The authors study a multiple period problem in which restocking can only be done every number  $m$  of visits; the matter is determined how many units of a type part crews will carry.

Teunter (2006) considers the trade-off between holding cost and service (measured by job fill-rate). He reformulated the knapsack heuristic proposed by Heeremans and Gelders so that it does consider the job-fill rate (and not only tour fill rate) and develops two heuristics: Job Heuristic JH and Part Heuristic PH.

Bijvank et al. (2010) move from a literature review and observe that often papers in literature impose several unrealistic assumptions for repair kit dimensioning. So they develop an algorithm that consists into 3 steps:

- determination of the order of the number of units to add to the repair kit for each part type;
- use of a greedy procedure to select the parts that are added to repair kit until the predefined service level is satisfied (this procedure is based on a ratio which measures the relative increase of the service level in relation to the increase of the holding costs)
- improvement and minimization procedure (by removing the units which were added to the repair kit in the last iteration and adds different parts).

Bijvank et al. (2010) discuss and compare the performance of algorithm in different conditions: small, large and representative instances.

Recently Gullu et al. (2013) provided a modeling and optimization framework for the kit planning problem with applications in health care context. They present a model for managing medical tools and implants inventories that incorporates several realistic characteristics of the system. Then they formulate product form expressions for the kit-readiness probability and finally they propose and test a heuristic for finding the base- stock levels

In order to enlarge our research and to transfer good methods or models from other similar contexts to RKP (in particular about FOs, costs and inventory policies) we examined also papers dealing with the general problem of spare/service parts that present analogies with RKP approach. In particular we selected papers about service parts inventory dimensioning in presence of space and/or budget constraints.

Cohen et al. (1989) propose a model which aim is costs minimization; they consider many different items cost (inventory holding, ordering, stockout and transportation).

Other authors (Yang et al., 2013; Alvarez et al., 2012) include in evaluations lateral transshipment costs, under the hypothesis that stock could be shared among technicians.

It is interesting to underline that different authors focus on different inventory management policies; Berman and Sapna, (2001) adopt continuous  $(s, S)$  policy, Yang et al. (2013), Alvarez et al. (2012) and Pince and Dekker (2011) adopt  $(S-1, S)$ . Wang et al. (2008) and Babai et al. (2008) adopt continuous  $(r, Q)$  policy; in particular Babai et al. (2008) make a comparison between  $(s, S)$  and  $(r, Q)$  policies.

#### 4. Implications/Limitations/Value

The research presented in the paper could represent the starting point for developing a new model that considers all the not sufficiently examined elements by literature, in order to contribute to a the development of managerially-relevant models. We think that a suboptimal solution, quite easy to implement by practitioners, could be very useful from the company managers' point of view.

The first element that could be scrutinized concerns costs evaluation. We previously discussed the differences among costs elements; in real conditions companies should find the model that minimizes all the logistics costs, while literature generally considers only some cost items.

At the same time, in order to be implementable, the model cannot be too computationally complex: for this reason it should be appreciated to develop new *Two-step-approach* model. It is interesting to observe that in real conditions it is not known *a priori* which is best performing inventory policy; the policy affects average stock levels, so RKP solution consists in choosing between to stock few SKUs in medium-high quantities or many SKUs in lower quantities and simultaneously to identify replenishment method. The 9 presented papers do not compare performance of different policies.

Second element that could enrich literature concerns the comparison between cost and service models. In company context both aspects are very relevant, because: from an efficiency point of view (internal perspective - company) it is necessary to minimize the sum of all incurred costs, included the ones caused by insufficient service to customer; from an effectiveness point of view (external perspective - customer) companies should assure maximum SL. So FO will consist in minimizing all the costs under SL constraint. Moreover it is very interesting for companies to verify that the set of part minimize overall costs (included the shortage ones) but achieve high service levels.

Third element regards demand forecasting. When we talk about service parts, one of the main features is the demand pattern: lumpy and low volume. For this reason it is interesting to investigate the role of demand forecasting, that is difficult to implement (especially for very low demand part) but could give information about stock quantities to put in the kit.

Future literature analyses could carry out a comparison among different policies, inventory strategies and allocation rules. The output is a management model for dimensioning service parts inventory on the van of technicians, that, moving from parts features, suggests which parts to stock and the inventory management parameters.

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**INVENTORY MANAGEMENT IN A DISTRIBUTION COMPANY AS A PART OF  
THE CORPORATE SOCIAL RESPONSIBILITY CONCEPT**

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Please note that the above paper will be handed out during Conference.

## Section 6 – Maritime Logistics

### DEVELOPMENT OF CONTAINER TRANSPORT - BARRIERS AND OPPORTUNITIES: CASE STUDY OF THE PORT OF KOPER

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#### ABSTRACT

The vision of the management of the Port of Koper is to become one of the best ports in Mediterranean connecting Central, Eastern and Western Europe with Mediterranean and Far East Countries. The Port of Koper is a member of NAPA (Nord Adriatic Ports Association - ports of Koper, Trieste, Venice, Ravenna and Rijeka). To obtain better service the ports of NAPA are going to invest efforts into the coordinated planning of road, rail and maritime infrastructure, as well as the harmonization of regulations and procedures in the field of port service provision. The global container transport increase amounts to about 8-10% on a yearly basis. The container transport increase in the Port of Koper was of 400% in the years from 2000 to 2008. The transport of containers in the year 2008 was 358,654 TEUs, in the year 2009 – 344,086 TEUs, in the year 2010 – 476,731 TEUs and in the year 2011- 589.314 TEUs. Despite the global recession the decline in container transport in the year 2009 was minimal. A great increase in transport followed in the year 2010 which was also a consequence of the introduction of the direct lines between Asia and the north Adriatic.

This paper aims to present and analyse supply chains of the flow of containerised goods through the Port of Koper, the changes which enable recent container boom, barriers and opportunities to handle even more containers in the future, current and future investments in new capacities.

**Key words:** Port of Koper, NAPA, container terminal, barriers and opportunities, new transport services, investments

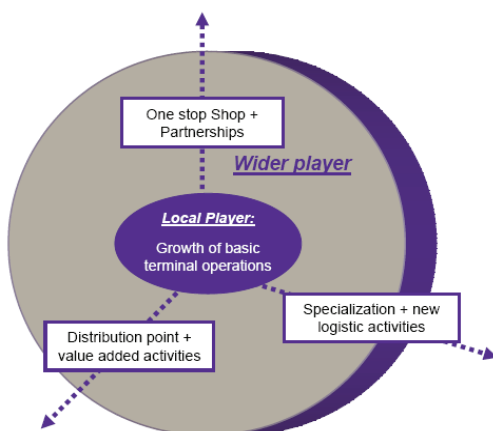
#### INTRODUCTION

Today, ports should be conceived as logistics and distribution centres that not only optimise the movement of goods and services within the entire transport and logistics chain, but also provide and add value to ultimate customers and users (Bichou 2009).

The strategy of the Port of Koper is based on the following basic directions:

- the universality of the range of port services offered on the highest quality level;
- the Port of Koper company ('Luka Koper') - a commodity distribution centre;
- an efficient information network and logistical connection with the world;
- stability and profitability of the operation in the long run.

The area of the Port of Koper has suffered from ecological degradation due to the presence of the port facilities, which is the reason why the port authorities are going to reduce the extent of coal and iron ore cargo and dedicate themselves more to cars and containers. Strategic orientation of the management of the Port of Koper is to increase the quantity of handled containers to 2.000.000 TEUs till the year 2025.



**Figure 4: Strategies of the Port of Koper**

Source: Port of Koper

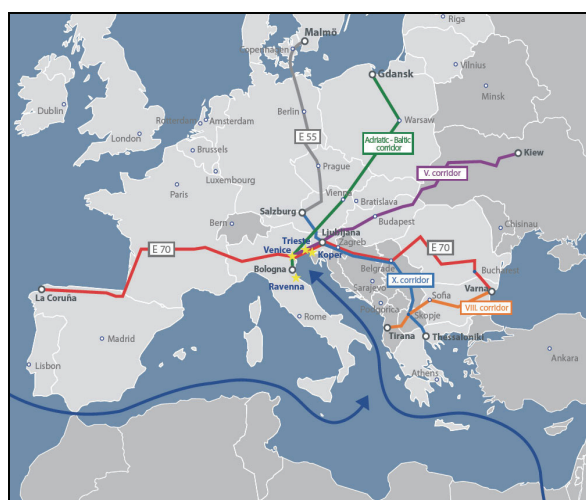
## THE PORT OF KOPER - MEMBER OF NAPA (NORD ADRIATIC PORTS ASSOCIATION)

### Position of the NAPA seaports

The five NAPA seaports (ports of Koper - Slovenia, Trieste, Venice, Ravenna - Italy and Rijeka - Croatia) are located at the northern tip of Adriatic sea, a natural waterway that penetrates deep into the middle of the European continent, thus providing the cheapest naval route from the Far East via Suez to Europe. The near-by fifth Pan-European transport corridor (Fig. 1) provides a quick-link to 500 million European consumers. Large commercial and industrial hubs like Vienna, Munich and Milan are just few hours drive away. The five entities combine their strengths in order to promote the Northern Adriatic route and present themselves as an alternative to the North-European ports. In addition, the association anticipates cooperation in the development of maritime and hinterland connections, visits from cruise lines, environmental protection, safety and information technology.

([www.portsofnapa.com](http://www.portsofnapa.com))

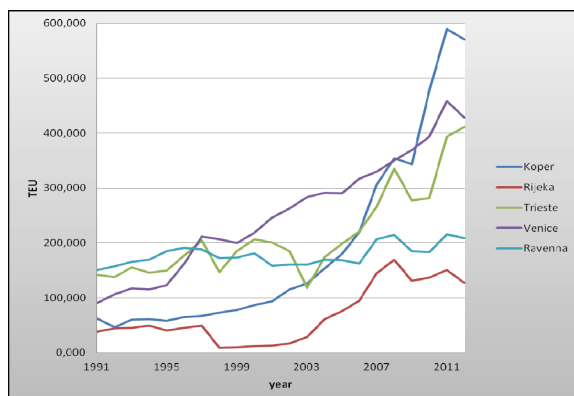
In addition to pursuing the intensive promotion of the southern gateway to the European continent, the Association is also active in national and European institutions which tailor European transport policy. Thanks to NAPA's efforts, the Adriatic-Baltic corridor (Fig. 1) was finally included among the nine high-priority corridors encompassed by the EU directive for the development of rail freight.



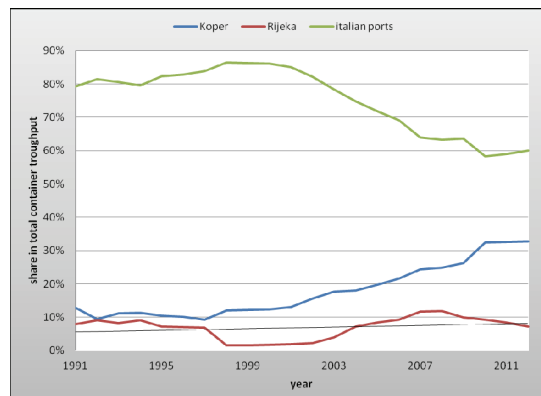
**Figure 1 - Main transport corridors**  
Source: NAPA ([www.portsofnapa.com](http://www.portsofnapa.com))

### Container throughput in the North Adriatic ports

The Fig. 2 shows that the total throughput in the last twenty years has exponential growth but the share between the ports shows some oscillation. In this period the container throughput in the Port of Koper had a growth by 14 % per year. In the year 2008 and 2009 when the financial and economic crises has started the throughput in the North Adriatic ports was decreased cca 15 % but the Port of Venice still had a slow growth (5%).



**Figure 2: Container throughput in North Adriatic ports**  
Source: Authors



**Figure 3: Market share between countries of North Adriatic ports**  
Source: Authors



The Figure 3 shows that only the port of Rijeka retains its share position. The market share of the ports of Ravenna, Venice and Trieste was on the beginning (1991) cca. 80% (now cca. 60 %). At the same time the share of the Port of Koper increased from cca.10% to cca. 30 %.

As the market potential for the NAPA ports in the container market in 2030 appears to be ambitious in terms of the absolute growth it implies +348% traffic growth from 2010 compared to 73% growth in the market as a whole and in terms of market share growing from the current 4.3% to reach 11.3% in 2030 (NAPA Container Market Study).

### **RECENT DEVELOPMENT OF THE CONTAINER TERMINAL**

Because a further increase in orders of ships of 7500 TEUs and over was expected an extension of 146 m of the first pier began to be built so that the entire length of the coast amounts today to 596 m (Fig. 4). In 2009 the port gained two transtainers and four post – panamax cranes (Fig. 4) for transport with ships of 7500 TEUs capacity.

The annual transport capacity increased to 600,000 TEUs with the purchase of new storing bridge cranes with stacking capacity of 4 or 5 containers in height, the repositioning of empty containers to new locations and acquiring new areas for full containers by doing so and with faster working of containers from the ship to the terminal and vice versa.



Container terminal 2002

Container terminal 2010

**Figure 4: Container terminal in the year 2002 and 2010**

Source: Port of Koper

### **Connections of the container terminal**

The terminal is connected with the Far East weekly with regular direct lines and through feeder service with important HUB ports in the Mediterranean (Malta, Piraeus, Gioia Tauro, Haifa) from where regular connections lead to all the continents of the world. As the maritime connection of the port is important so is also the so called land connection. In this way the Port of Koper is connected to important trade centres of the middle and east Europe by regular railway connections and the highway cross. The railway transport of containers out and into the container terminal of the Port of Koper is performed by six different transport companies. Today 7 block trains are daily executed from the Port of Koper to various destinations like: Ljubljana, Budapest, Žilina, Graz. The execution of road freight transport is left to the local transport companies.

Beside the great increase in transport also the portion of container import and export states is changing. The Slovenian portion in the entire transport is steadily decreasing, partly also because of the crisis in the Slovenian economy. The transport in transit is increasing, especially with Austria, Slovakia and the Czech Republic. The transport with Italy and Germany does not reach the desired growth. A lot of unexploited possibilities

are still in the transport of goods with Germany or Bavaria and Austria because they perform the major part of their container transport through north European ports.

YEAR	2004	2005	2006	2007	2008	2009	2010	2011
TEUs	17645	21202	25626	30352	35865	34408	47673	58931
	8	5	5	4	4	6	1	4

**Table 1: Container transport in the Port of Koper in the years 2004–2011(TEUs)**

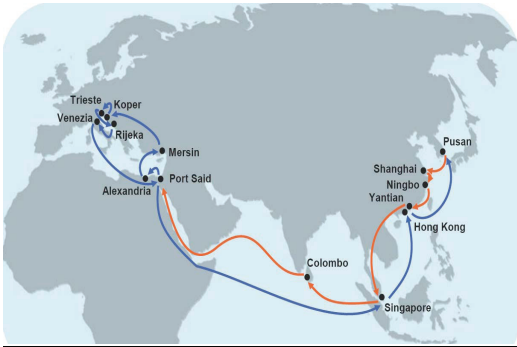
Source: Port of Koper

**Container services – direct services out/in Koper**

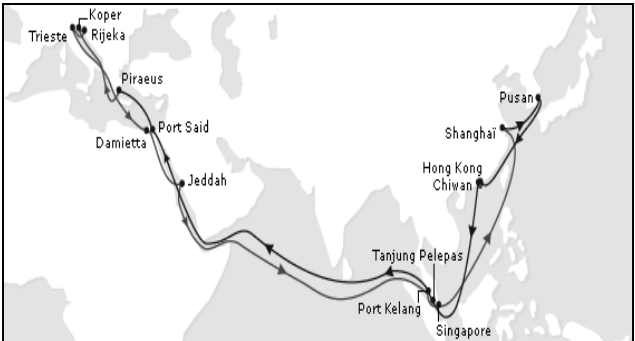
The terminal connectedness is one of the key information for business partners. Regarding maritime routes the container terminal is connected with other ports and regions on the basis of 14 so called services.

We can separate the maritime connectedness into two categories namely to direct services from/to the Far East (such are two) and the rest of 12 services of which the ports are located in the Mediterranean. These services are also called “feeder” services because they visit among others also important Mediterranean HUB ports like Gioia Tauro, Malta, Piraeus, Haifa, Taranto, etc. from which maritime routes lead to all the continents of the world.

On the figure 5 a newly implemented service (from June 2010 on) with the Far East is shown, which has been established together by four shipping companies namely Hanjin Shipping, Hyundai Merchant Marine, United Arab Shipping Company and Yang Ming Marine Transport Corporation. This is a very important service for the container terminal because it flourished in the crisis or post crisis period. In the aforementioned service eight different ships sail – two per each shipping company, which weekly visit the Port of Koper.



**Figure 5: Newly implemented direct service with the Far East**  
Source: Port of Koper



**Figure 6: Newly implemented direct service with the Far East intended for the automobile industry**  
Source: <http://www.cma-cgm.com>

The other direct service (Fig. 6) is performed by the shipping companies MAERSK LINE and CMA CGM. The container line between Asia and the north Adriatic is supplying markets in Slovenia, Slovakia, the Czech Republic, Austria, south Germany, Serbia, Bosnia and Herzegovina, Hungary and Croatia. The entire route takes 63 days. The ships capacities are from 6200 to 7000 TEUs.

The weekly service is maintained with 9 ships between 16 ports - Shanghai, Pusan, Hong Kong, Chiwan, Tanjug Pelepas, Port Kelang, Port Said, Trieste, Koper, Rijeka, Trieste, Damietta, Port Said , Suez Canal, Jeddah, Port Kelang, Singapore in Shanghai.

For the container business on this line that is intended for the automobile industry (JUST IN TIME) is typical that:

- Freight comes from South Korea
- Freight presents automobile parts destined to the "Kia" and "Hyundai" factory
- It is approx. 140,000 TEUs on an annual level (approx. 1,250,000 tons of cargo)
- It is 2 ship services (2x a week)
- Containers have priority when unloading from ships holds
- Freight "starts" from port in a few hours after unloading from the ship – certain containers even in 30 minutes!!!
- The quantity increases from year to year and similar strategy is introduced also in other freights – electronics

### **BARRIERS AND OPPORTUNITIES TO HANDLE EVEN MORE CONTAINERS IN THE FUTURE**

The business orientation of the Port of Koper to develop principal infrastructure and acquire new business partners in the container transport area has proved to be correct. Great financial investments in the extension of the container shore, expansion of storing space and purchasing of specialized transport equipment has proved in the big increase in transport in the year 2010. Despite the global crisis the increase of transport was approx. 40%.

The quantity of transported containers is reaching enviable numbers but the future growth is threatened. In the year 2012 shipping company Hyundai Merchant Marine has directed its weekly service (Fig. 6) to Hamburg so that the Port of Koper has lost 60,000 TEUs (10%). To find new partners and containers NAPA has presented its activities on prospectiv Indian market ( Mumbai).

What is noticeable today is the obvious increase in orders of even bigger container ships of 11000 TEUs and over (Tb. 2), which in turn means a larger margin for ship-owners sending their ships to transport containers on the main East-West, Asia-Europe, and Asia-North America routes.

	<b>3,718-6,099 teu</b>	<b>6,100-7,399 teu</b>	<b>7,400-10,999 teu</b>	<b>11,000+ teu</b>	<b>Total</b>
1988-1990	5	0	0	0	5
1991-1995	24	0	0	0	24
1996-2000	71	14	20	0	105
2001-2005	112	70	72	0	254
2006	12	21	60	2	95
2007	8	25	35	5	73
2008	10	29	46	4	89
2009	4	22	25	10	61
2010	9	25	34	26	94
<b>In use</b>	<b>255</b>	<b>206</b>	<b>292</b>	<b>47</b>	<b>800</b>
2011	34	31	37	56	158
2012	32	17	25	48	122
2013	4	6	30	24	64
2014	0	0	15	6	21
2015	0	0	1	3	4
<b>Orderd</b>	<b>70</b>	<b>54</b>	<b>108</b>	<b>137</b>	<b>369</b>

**Table 2: Post-Panamax container ships in use and orderd on 1. january 2011**

*Source: L'loyds shipping economist, 2011*

Ships of over 11000 TEUs are to have a major influence on container terminals because these terminals will need to adjust their infrastructure and reconstruct their suprastructure. That's why the second extension of the first pier began to be built (+100 m). At the same time the works to reach the depth of 15 m (today 11 m) have started (Fig. 7).

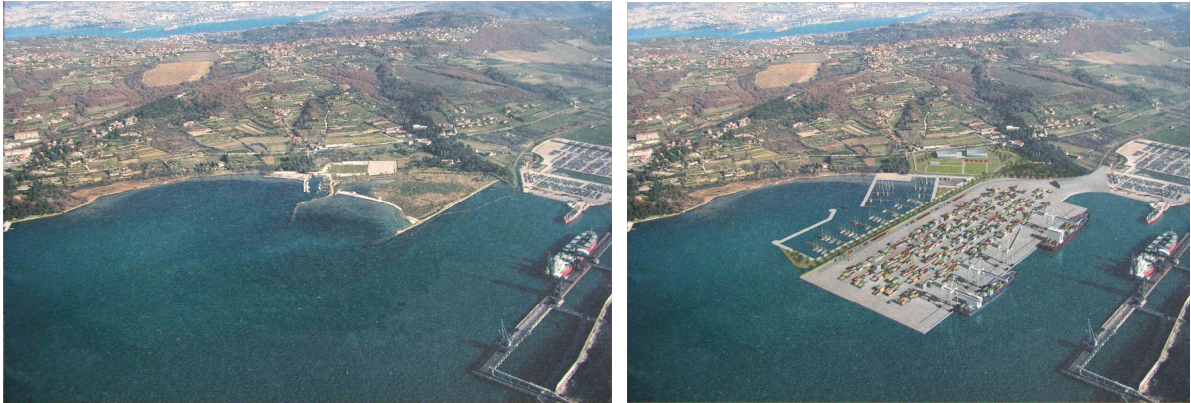


**Figure 7: Works on the first pier**  
Source: Port of Koper

In the future developmental possibilities are seen in the construction of the new third pier (Fig. 8) to be able to receive the latest container ships which are not presently able to dock on the pier one due to its shallowness. From the point of view of infrastructure the minimal standards to be met are 350 metres of shore, 14, 5 metres of sea depth as well as shore area capable of carrying »post-panamax« cranes.

The construction of the third pier is planned to be carried out in two phases:

1. 700 m of the quay area in length enabling transshipment of 800,000 TEU.
2. 350 m in length (total 1050 m) enabling total transshipment of 1,000,000 TEU.



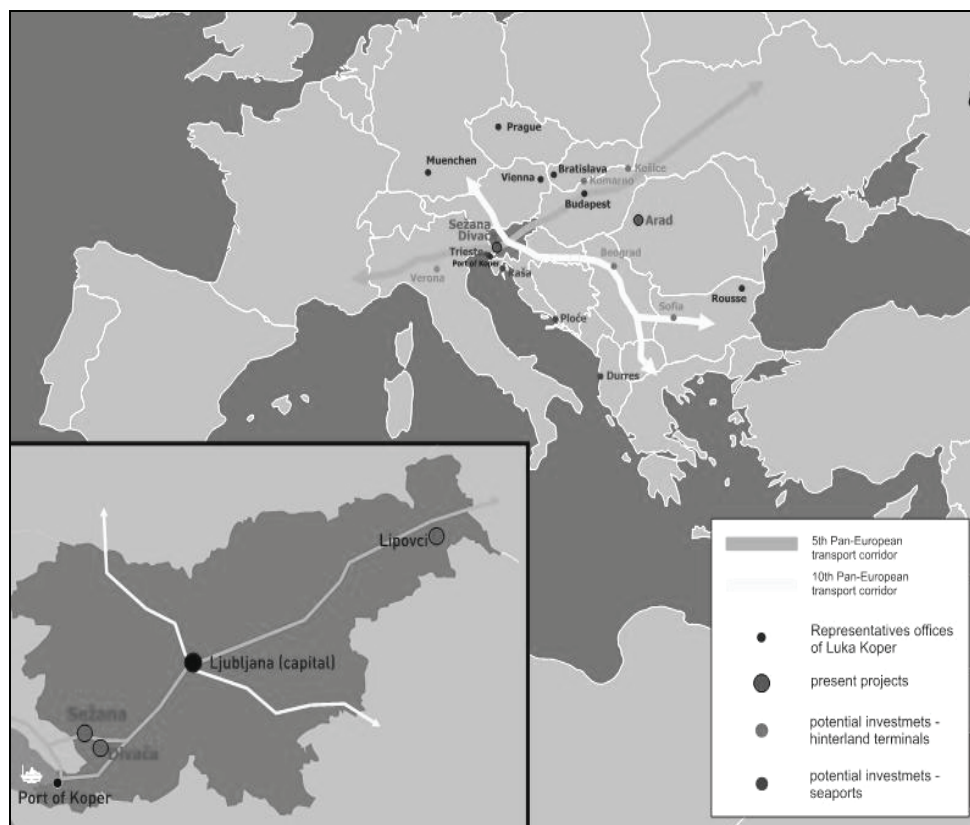
**Figure 8: Present and the future Pier III**  
Source: Port of Koper

Today, whole supply chains are competing, not just ports among themselves. Ports are important elements in the logistics chain and their level of integration with inland transport is very important. Main reasons for this need is that costs for inland transport

are generally higher than maritime transport costs and many delays can occur in the inland side of the chain such as congestion, limited infrastructure etc. The portion of inland costs in the total costs of container shipping would range from 40% to 80% (Notteboom 2004).

Moreover, there are some important developmental reserves as far as the effectiveness of railway transport is concerned. These should be brought about by the privatisation and by the restructuralisation of the sector itself, which can mostly be seen in the Central and Eastern European countries. For one thing, organising the so called »block trains« in the Adriatic basin is a strategy that hasn't been exploited to the fullest. In this respect the northern ports have the upper hand. In order for the Port of Koper to be able to load more container number of »blocks trains« should increase. In the near future modernisation of the Koper-Divača railway connection will increase cargo flow by 30%. The construction of the second railway track has a net worth of 700 Million Euro and forms a part of the Fifth Corridor from Lyon to Kiev, which puts it on the priority list of projects co-funded by the European Union.

Beside the aforementioned activities, the Port of Koper wishes to develop new activities from which the cooperation of the Port of Koper with existing inland terminals (logistic centres) and establishing of new ones positioned between eastern and western Europe stand out. The Adria Terminali (Sežana), regional logistics center "Panonija" (Lipovci), inland container hub-rail port Arad as well as Adria transport d.o.o. will give a strong support to the terminal activities in the Port of Koper providing efficient logistic solutions for south transport route (Fig. 9).



**Figure 9 - Location of the Adria Terminali (Sežana), regional logistics center "Panonija" (Lipovci) and inland container hub-rail port Arad**

Source: The Port of Koper

Terminals are the main regulators of freight flows and as such considerably influence the setting and operation of supply chains in terms of location, capacity and reliability (Jean-Paul Rodrigue & Theo Notteboom, 2008).

## **CONCLUSION**

Today, the countries of Central and Eastern Europe (CEE) have developed into a growing and promising part of Europe. The vision of the NAPA seaports is to form a European logistics platform with regard to servicing these markets as well as the markets of the Far East.

According to the estimation of the management of the Port of Koper some 80000 – 100000 TEUs are lost each year because container ships of 11000 TEUs and over are not able to enter the Port of Koper.

In the long term strategy there is also the construction of the third pier with 1 mill. TEUs capacity. Because ports are important elements in the logistic chain and their level of integration with inland transport is very important a second railway track from Koper to Divača and the upgrade of the rest of the railway tracks in Slovenia is necessary. There are also some (old) ideas to build railway connection as well between the Port of Koper and the Port of Trieste.

New projects and potential investments are important steps within the development of the Port of Koper enhancing it's performance and increasing the market share.

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# **BENCHMARKING THE OPERATIONAL EFFICIENCY OF NIGERIA SEAPORT TERMINALS USING DATA ENVELOPMENT ANALYSIS (DEA)**

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## **1.0 INTRODUCTION:**

Nigeria with its crude oil and abundant natural resources has established trade ties with different countries and Nigerian seaports have been experiencing a rise in throughput volume in recent years. In spite of this, there is a widely held view that ports in Nigeria are inefficient and perform below international standard despite the massive port reforms that took place in 2006. The wholesale concession led to the emergence of many terminals both big and small operated by different operators and placed Nigeria seaports at the centre focus of private participation in Sub-Saharan Africa. With the growing number of countries adopting the landlord model of port administration, many terminals are in the hands of different private operators, therefore the need arises to evaluate the performance of these terminals.

Hence, this study evaluates the operating efficiency of ten out of twenty different terminals carved out of six Nigerian seaports in 2006 during a concession programme based on the following objectives: *i)* estimate the terminal efficiency by different cargo types (i.e. container and dry-bulk cargo), *ii)* identify the key performance factors, along technology, scale and input efficiencies; and *iii)* highlight some general policy issues on terminal efficiency that is of benefit to managers.

## **2.0 LITERATURE REVIEW**

There is an array of studies that have applied DEA to benchmark the performance of container terminals. The first attempt in applying DEA to ports was by Roll and Hayuth (1993) although no real data was used. Thereafter Martinez-Budria et al. (1999) compared the performance of 26 Spanish ports. Tongzon (2001) studied the efficiency of 16 Australian ports; while So et al (2007) ranked the efficiency of major container terminals in Northeast Asia and Cullinane and Wang (2010) estimated the efficiency of 25 leading World container terminals. Cullinane et al. (2004), and Turner, Windle and Dresner (2004) assessed 26 North American seaports whereas Park and De (2004), Min and Park (2005) focused on Korea seaports; Barros and Athanassiou (2004) study was based on a sample of 6 ports in Greece and Portugal; Wang and Cullinane (2006) focused on 104 terminals' efficiency in Pan European countries; Barros (2006) investigation was on 24 Italian ports while Munisamy and Singh (2011) assessed the technical and scale efficiency of 69 major Asian container ports. There are a few port efficiency studies on Latin America a developing region. Estache, Gonzalez and Trujillo (2001) studied 14 Mexican ports whereas Rios and Macada (2006) evaluated 23 terminals in Brazil, Argentina, and Uruguay only while Munisamy and Jun (2013) studied the efficiency of Latin American container seaports using DEA.

However there is no study that dealt specifically on African seaport container terminals. The few studies based on the ports in the continent are: Al-Eraqi et al, (2009) used DEA and Stochastic Frontier Analysis (SFA) to evaluate the location efficiency of Arabian and East African seaports, Valentine (2001) undertook a comparison of 15 African ports in 10 countries using DEA. In the same vein Barros et al, (2010) examined the technical efficiency of major African ports located in Nigeria, Angola and Mozambique using Bootstrapped DEA while Ibe and Onwuegbuchunam (2011) x-rayed the productivity and efficiency of Nigeria's seaports using stochastic frontier model.

Most of these studies used DEA to benchmark container terminals except Oliveira and Cariou (2011) that studied the efficiency of 122 coal and iron ore ports in selected countries using DEA and Merk and Dang (2012) that studied the efficiency of World Port terminals in container and bulk.

A diagnostic examination of all these studies reveals the use of inconsistency units of analysis i.e. container ports and container terminal were used interchangeably. But large

ports often have multiple terminals for instance Port Rotterdam has both large container such as European Container Terminal (ECT) and other small terminals like Uniport which cannot handle large vessels. In addition, the terminal operators of these terminals are different as well as there are processes of cargo handling. A DEA analysis is only rational if the comparison is between ports/terminals of similar production functions. That is why Alderton (1999) and de Koster (2009) asserts that for data compatibility and comparability researchers should focus on terminals and if possible import/export and transshipment terminal should be further segregated because the production processes differ.

### 3.0 Data Envelopment Analysis (DEA) MODELLING

The method of estimating deviations from a production frontier with a single input and a single output was first introduced by Farrell (1957). He defined efficiency as a ratio of output to input. It was later extended to evaluating multiple inputs and outputs by Farrell and Fieldhouse (1962) by using a weighted average of efficient units as a hypothetical efficient unit. However, the complexity involved in obtaining a common set of weights to be used in calculating relative efficiency led to the introduction of DEA-CCR by Charnes, Cooper and Rhodes (1978), later Banker, Charnes and Cooper (1984) came up with the DEA-BCC model. The only distinction between the two is on the assumption of scale while DEA-CCR is based on constant returns to scale technology DEA-BCC is rooted on variable returns to scale technology.

Mathematically, DEA output oriented model can be expressed thus; let inputs be denoted as  $x_k = (x_{1k}, x_{2k}, \dots, x_{Mk}) \in R_+^M$ , when combined in a production process, produce outputs  $y_k = (y_{1k}, y_{2k}, \dots, y_{Nk}) \in R_+^N$ , where  $x_k$  and  $y_k$  are row vectors and form the  $k^{th}$  rows of data matrices X & Y respectively. Also let,  $\lambda = (\lambda_1, \lambda_2, \dots, \lambda_k) \in R_+^k$  be a non-negative vector which forms the  $k^{th}$  linear combination of firms, equally  $e = (1, 1, \dots, 1)$  is a vector of value unity. Then output oriented efficiency measurement can be written as a series of  $k$  linear programming envelopment problems with the constraints differentiating between DEA-CCR and DEA-BCC as shown equations (1-5). Thus let U be a scalar quantity such that  $1 \leq U \leq \infty$  and U-1 be the proportional increase in outputs that could be achieved by the  $i^{th}$  DMU, with input quantities held constant, this gives the linear programming equation:

$$\text{Max } U \quad (1)$$

Subject to

$$U y_k^j - Y^j \alpha \leq 0 \quad (2)$$

$$X^i \alpha - x_k^i \leq 0 \quad (3)$$

$$\alpha \geq 0 \text{ (DEA - CCR)} \quad (4)$$

$$e \alpha^t = 1 \text{ (DEA-BCC)} \quad (5)$$

The combinations of equations (1) to (4) and (1) to (5), respectively, give the DEA-CCR and DEA-BCC models. The output-oriented measure of technical efficiency of the  $k^{th}$  DMU, denoted by  $TE_k$ , can be computed by equation (6).

$$TE_k = 1/U_k \quad (6)$$

However, the technical efficiency derived from DEA-CCR and DEA-BCC model is then used to obtain a measure of scale efficiency, as shown in Equation (7) (Cooper et al., 2000),

$$SE_k = U_{CCR_k} / U_{BCC_k} \quad (7)$$

Let  $SE_k$  represent the scale efficiency of the  $k^{th}$  DMU, while  $U_{CCR_k}$  and  $U_{BCC_k}$  are the technical efficiency measures for DMU K derived from applying the DEA-CCR and DEA-BCC models, respectively.  $SE_k = 1$  connotes scale efficiency whereas  $SE_k < 1$  denotes scale inefficiency.



## **4.0 METHODOLOGY**

This aspect of the study deals with the application of the DEA model to container and dry bulk cargo (DBC) terminals, the units of analysis, sources of data and variable specification.

### **4.1 Units of Analysis**

The study examined the 6 container terminals APMT (AP Moller Terminals), Brawal, FSL (Five-Star Logistics), PCHS (Port Cargo Handling Services), PTML (Port Terminal Multiservices Limited) and TICT (Tin-can Island Container Terminal) and 4 Dry Bulk cargo terminals ABTL (Apapa Bulk Terminal Limited), GDNL (Greenview Development Nigeria Limited), JOSD (Josepdam Nigeria limited) and PTOL (Port and Terminal Operations Limited) that were carved out from six Nigeria ports after concession. It should be noted that although these two types of terminals may be operating at the same port, the infrastructure, superstructure and space requirements are different because the nature of cargo handling and operation. As a result the benchmarking in this research distinguished these two types of terminals and carried out two benchmarking analysis based on type of cargo handled by each terminal.

### **4.1 Sources of Data**

The data is sourced from the yearly compliance report to the Nigerian Ports Authority (NPA), the annual reports of the respective terminal operators and the NPA website. Data was collected from six container and four DBC terminals from 2006-2011.

### **4.2 Variable Selection**

The sensitivity of DEA to variable selection cannot be over emphasized because as the number of variables increases the discriminatory capability of DEA diminishes. This is because addition of more variables may cause inefficient variables to become efficient (Smith, 1997). DEA has no inbuilt checks in the model for miss-specified variables as a result of wrong variable selection (Galagedera and Silvapulle, 2003). There is no theory on the choice of variables although Raab and Lichy (2002) suggested a general rule of thumb –the minimum number of DMUs should be greater than three times the combined number of inputs and outputs. In this research, each set of terminals i.e. container and DBC has six variables used for the analysis, two outputs and four inputs based on the rule a good minimum data set should contain 18 data points, but this study made use of 36 data points and 24 data points respectively. As a result of this and for DEA to retain its discriminatory power, six variables that most reflect the production function of a port terminal were chosen.

For the container terminals the four input variables selected are: number of berths, terminal area in hectares, and total number of equipments in use by each terminal and the total number of staff. Stevedore labour would have been arguably the most important figure to represent labour in a container terminal production but lack of data on the subject, yearly staff strength of the terminals is used as a proxy for labour input. While the output variables are captured by annual container throughput in TEUs and ship turnaround time, almost all studies have treated throughput as an output variable because it is the basis of comparison of container terminals in relation to size, investment magnitude or activity levels. Turnaround time is used as an output variable in this study as one of the main objectives of Nigeria's seaport concessions is to reduce the time ships stay at ports in order to attract more ships to Nigeria ports.

In terms of DBC terminals for vessel services although Oliveira and Cariou (2011) used ship draught and length in metres but for this study we made use of quay length because the terminal comparison in this study is based on the resources available to each terminal operator after concession to see which operator made judicious use of the resources allocated. For loading/unloading total number of equipment in use by each operator is selected contrary to loading rate used by Oliveira and Cariou (2011) and consistent with Merk and Dang (2012). Also, total terminal capacity allocated to each terminal operator is selected to represent the amount of space available for each operator for storage and the number of staff employed by each terminal as a proxy for stevedore labour. Finally the yearly throughput in tons and turnaround time of ships in days were selected to represent output variables to capture both operator and consumer perspectives.

### 4.3 Analysis

The DEA optimisation software Frontier Analyst version 4.0 (Banxia Holdings Ltd, 2012) was used to estimate the efficiency scores. In the estimation of the efficiency of the 6 container and 4 dry bulk terminals Nigerian from 2006-2011 the study employed DEA output orientation because in practical terms improving the efficiency of terminals increasing changeable outputs may be more appropriate than decreasing the given inputs. The study implemented both the variable returns to scale (VRS) and the constant returns (CRS) to scale assumption so that smaller terminals who may be disadvantaged in the CRS assumption may reflect efficiency scores from factors other than production scale.

### 5.0 DISCUSSION OF RESULTS

The average technical and scale efficiency for the period under review (2006-2011) for each of the seaport terminals i.e. container and DBC is presented in tables 5.1 and 5.2 respectively. The ratio of the overall efficiency score (CCR) and the technical efficiency score (BCC) gives the scale efficiency (SE). A mean efficiency of 100% indicate that the terminal operated efficiently during the observation period 2006-2011 but efficiency scores less than 100% shows an overall inefficient performance for the same period.

#### 5.1 Benchmarking operational performance of container terminals

**Table 5.1: Container terminal DEA-CCR/BCC panel efficiency scores**

TERMINALS	EFFICIENCY SCORES (100="EFFICIENT")											
	2006		2007		2008		2009		2010		2011	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
APMT	56.2	73.6	95	100	93.6	100	60	66.3	70.5	79.2	96.8	100
BRAWAL	100	100	62.9	100	49.8	77.4	100	100	59.5	60.1	58.3	58.9
FSL	85.6	88.2	100	100	100	100	100	100	100	100	100	100
PCHS	89.4	100	100	100	100	100	98	100	99.1	100	100	100
PTMT	84.8	100	97.9	100	100	100	100	100	100	100	72.3	72.3
TICT	81.8	82	91.5	92.8	94.4	96.2	96.6	99	99.2	100	100	100
MEAN	83	90.6	91.2	98.8	89.6	95.6	92.4	94.2	88.1	89.9	87.9	88.5
STDEV	14.6	11.3	14.2	2.9	19.7	9	16	13.7	18.2	16.8	18.1	18.3

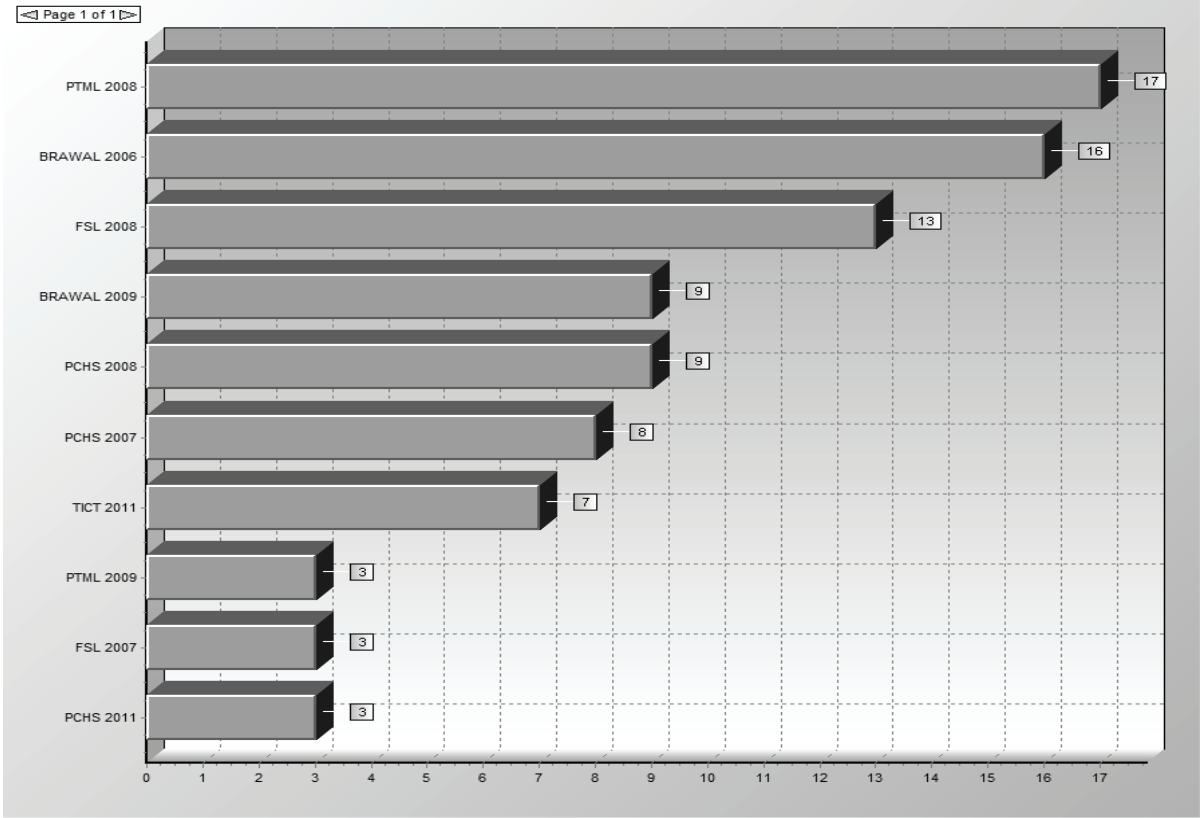
The result of the container terminal analysis in table 5.1 shows that all the terminals have experienced varying levels of efficiency and none of the terminals is 100% efficient for the whole period although there are efficient operations by terminals in some of the years. The highest fluctuation and lowest efficiency is by Brawal with a mean of 71.75% and standard deviation of 22.3%. While PCHS terminal with average DEA-BCC score of 100% is considered technically efficient, its overall efficiency represented by DEA-CCR is 97.75 is also the highest efficiency, therefore PCHS is the most efficient container terminal in Nigeria for the period 2006-2011.

A Pearson correlation coefficient between the efficiency rankings obtained from CCR and BCC analysis is 0.99 ( $p < 0.05$ ). The positive and strong correlation indicates that the rank of each terminal obtained from the application of the two approaches is similar. The implication of this apparently is that methodology has no impact on the estimated average scores. These results is consistent with what is obtainable in other studies that the efficiency score computed from CCR model is less than or equal to the corresponding BCC efficiency scores (Banker et al; 1994).

The DEA method has been described as a sufficient tool for benchmarking by Bergendahl (1998) and Mostafa (2009) because it allows for the identification of a group of efficient DMUs for each inefficient one. The identified efficient group may be used by managers to set operational goals for the non-efficient counterpart by putting the various input-output variable mixes of the efficient DMUs. From the DEA analysis a reference set is obtained for the inefficient container terminals. The reference set or the peer group shows which of the efficient container terminal an inefficient container terminal is closest in combination of inputs and outputs. While, efficient container terminals which appear infrequently in the reference set of other container terminals may probably have a very uncommon input-output mix and hence may not be an appropriate example for other inefficient container terminals.

Therefore, from figure1, of the 10 efficient container terminals the one that appeared most regularly as peer (i.e. benchmark) is PTML2008 (17 times) followed by Brawal2006 (16 times) then FSL (13 times), etc. Therefore, the reference frequency can be taken as a measure of the degree to which the performance of an efficient container terminal can be used as a benchmark for the inefficient ones. Therefore, PTML terminal operation in 2008 which is referenced 17times is the benchmark operation for other terminals to emulate; this may not be surprising as the terminal is the only one that started operation on build operate and transfer (BOT) basis. Although PCHS is the most efficient terminal but its operation is not considered as benchmark as it has an unusual input/output mix.

**Figure 1: Container Terminals CCR model reference frequencies**



**5.2 Benchmarking operational efficiency DBC terminals**

**Table 5.2: DBC terminal DEA-CCR/BCC PANEL efficiency scores**

TERMINALS	EFFICIENCY SCORES (100="EFFICIENT")											
	2006		2007		2008		2009		2010		2011	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
ABTL	93.6	97.1	100	100	99	100	100	100	89.8	89.8	100	100
GDNL	62.6	92.3	100	100	100	100	97.5	100	85.6	92.8	96.9	100
JOSD	90.7	100	100	100	93.2	100	100	100	100	100	95.5	96.8
PTOL	100	100	66.2	70.8	75.7	78.9	76.9	83	72	78.2	74.8	85.6
MEAN	86.7	97.4	91.6	92.7	92	94.7	93.6	95.6	86.9	90.2	91.8	95.6
STDEV	16.5	3.6	16.9	14.6	11.3	10.6	11.2	8.8	11.6	9.1	11.5	6.8

The result of efficiency scores in Table5.2 shows a fluctuating but high efficiency scores for the observation period 2006-2011. ABTL terminal has the highest average efficiency score 97.1% for the CCR model while JOSD is the most technically efficient with average BCC score of 99.5%. JOSD operation is efficient technically for most of the period except in 2011. The weakest operation is by PTOL in 2007 which suffered mainly from technical inefficiency. The correlation between the CCR and the BCC efficiency scores is 0.96 (p<0.05). As observed earlier in the container terminal analysis the positive and strong correlation indicates that the rank of each terminal obtained from the application of the two approaches is similar. However, the correlation between annual throughput and efficiency scores (0.37) is weak but positive which indicates that the sources of inefficiency in bulk terminals in Nigeria seaports may not be scale. This is at variance with Oliveira and Cariou (2011) conclusion that the source of inefficiency in bulk cargo ports is scale.

**Figure 2: DBC Terminal CCR model reference frequencies**

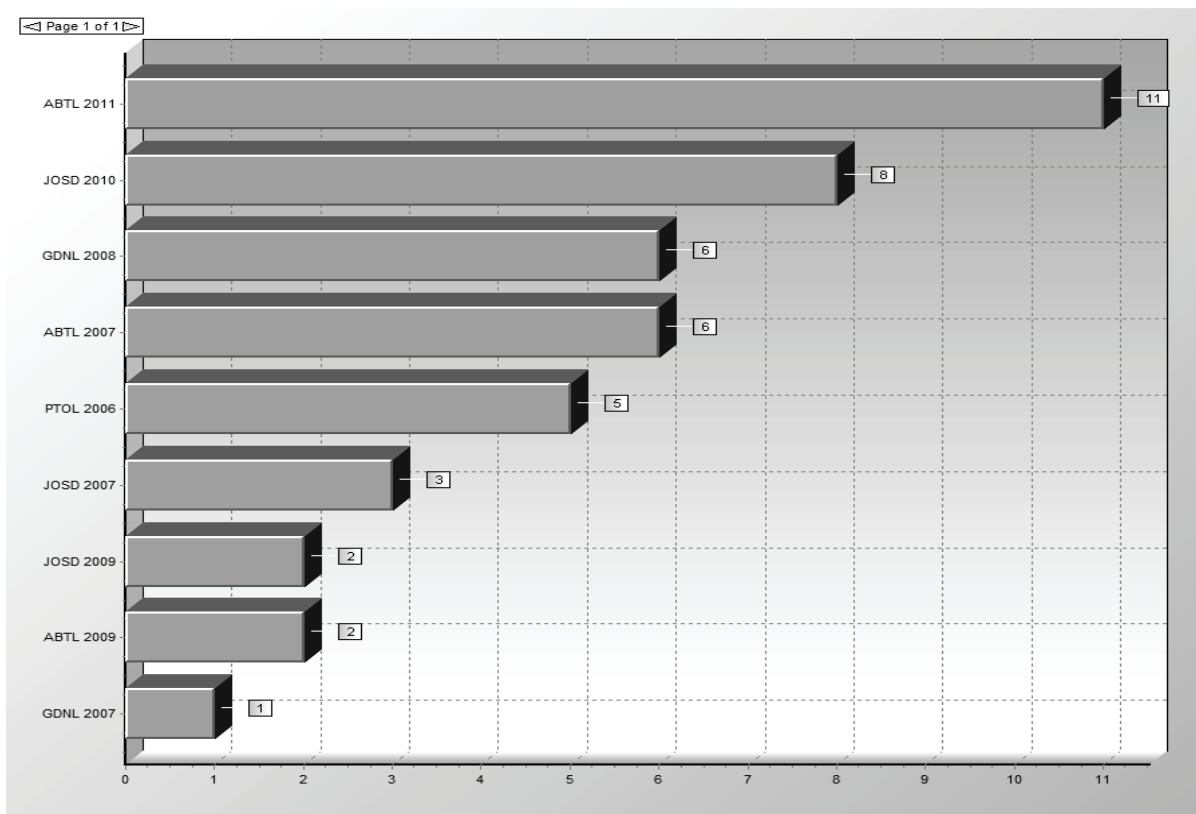


Figure 2 shows the reference frequency of DBC terminals that is on the frontier nearest to each inefficient DBC terminal in the sample set. The DBC terminal operation in a particular year that appears more in the reference set is ABTL2011 it is an example of operating performer. From the analysis there are 9 efficient terminal operations and 15 inefficient operations and ABTL2011 featured 10 times as a top performer that inefficient terminal operations in the data set could emulate in order to be efficient. In summary ABTL2011 which is referenced 10 times is the best benchmark operation for the inefficient bulk terminal to emulate.

## 6.0 CONCLUSION

Systematic evaluation of terminal efficiency by way of benchmarking is an important technique terminal operators/managers can employ to enhance terminal efficiency. Unlike the use of single performance indicators, the benchmarking technique used in this study employed the DEA approach which offers terminal operators a robust overall assessment of their terminals. In addition, an all round efficiency measure, give terminal managers and local port authorities the leverage to set their own priorities, and identify areas where investment is needed to secure efficiency gains.

The study reveals that majority of the terminals in the sample are operating well under variable returns to scale (VRS) and very few are operating optimally under constant returns to scale (CRS). The implication is that terminal operators should consider scale factors when planning expansion of terminal facilities and resources. Consequently, terminals that operate at increasing returns to scale could attain higher levels of efficiency by increasing their scale of operations. This can be accomplished by expanding input capacity; through mergers, acquisitions and building alliances with shipping organisations or with terminal operators in other ports. Conversely the terminals that operate at decreasing returns to scale could outsource part of its operation in order to operate optimally.

One useful application of this study is that it could help the regulator the Nigeria ports authority (NPA) to publish a ranking of the terminals based on the type of cargo. Such

ranking could stimulate public interest on the performance of the terminals, improve accountability and motivate terminal operators to seek for performance improvement. Lastly, it is expected that managers of inefficient terminals should learn from the practices of their efficient counterparts in order to improve their operations.

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# WHAT DESIGN AND INFLUENCING FACTORS IMPACT THE PERFORMANCE OF MARITIME BUSINESS NETWORKS? RESULTS FROM AN EMPIRICAL ANALYSIS OF THE MARITIME INDUSTRY IN BREMEN

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## ABSTRACT

The purpose of this paper is to show the correlation between the influential value chain design factors and the performance level of business networks in the maritime industry. The paper is based on the basic notions of Möller (2006a and 2006b) that have been adapted to the our research context that is regional and focusing on one particular sector. We raise the question on which of the identified factors and management tasks are relevant for the design as well as the success of the business network.

## RESEARCH BACKGROUND

In order to maintain their future competitiveness, firms are required to adapt to changing business conditions permanently. Beyond this perspective and besides the increasing dynamics in many markets, many companies are forced to rethink their organization structures. Thereby we are able to observe that companies have focused on their core competences and have outsourced other elements of their operations to other companies. Such behavior though increases the necessity build up business networks for cooperating with other companies in the supply and value chains (Möller 2006a, 1 or Scholz-Reiter and Hinrichs 2009, 25). The network organization is here an effective governance form that more and more companies are choosing (see Bauknecht et al. 2012, 307). Following Manshina (2010, 26), a business network is understood as a special form of an inter-firm alliance. By executing tasks in a joint manner, the involved companies are able to increase their competitiveness (Schmidt 2012, 16 or Möller 2006a, 62). The network set up is chosen because the actors are not be able to achieve the same result as if they would try to perform the activities in an isolated manner (Manshina 2010, 39). However, any successful business network requires a significant effort in organization and coordination (Bogenstahl 2012 or Sydow 1992). This is also necessary for avoiding some disadvantages and risks to be such as the lack of network management, lack of consideration of environmental aspects, partial dependencies, cost disadvantages, loss of know-how or decreasing innovation capacity (Manshina 2010, 45).

## MODEL DEVELOPMENT

The theoretical frame of reference that was chosen to examine business networks of the maritime industry in Bremen consist according to Möller (2006a and 2006b) of three elements: influential factors of the network, design of the value chain system and performance level. The influential factors consist of the elements trust, participation and strategic importance of the network (Möller 2006b, 1053). Trust is considered as "lubricant" of inter-organizational relations and is a crucial ingredient for business networks (Möller 2006a, 186; Bogenstahl 2012, 56 or Schweer and Siebertz-Reckzeh 2012, 18). However, trust cannot be directly observed, which makes it necessary to measure the mental attitude of one business network partner towards another one (Bogenstahl 2012, 56). Participation is seen as the active involvement in the decision-making process of business network (Möller 2006b, 1056). Participation builds on an increased identification of the actors with the business network and therefore increases the improved exchange of resources as well as the willingness to perform within the network. Participative behavior reduces opportunistic behavior, which however increases

the need for coordination between the business network partners in order to optimize the adjustments. As the joint efforts promise better results than an individual effort, the intensity of the strategic importance of a business network depends on the expectations towards the performance of the business network (Möller 2006b, 1056).

The design of the value chain system consists of four dynamic tasks: selection, allocation, regulation and evaluation (Sydow and Lerch 2011, 373). These four tasks are seen as the major areas of the network management (Möller 2006b, 1057). Selection though refers to the specific selection of network partners including positive as well as negative criteria. Network partners need to be adequate meaning that the competences and intentions of the potential partners fit to the objectives of the network (Sydow 2010, 395). Having the wrong partner in the business network can negatively influence the performance of the network. Allocation then means the distribution of tasks resources and competences to the individual partners (Sydow 2010, 397). A more efficient coordination regarding the division of tasks and resources can be ensured by good information systems (Möller 2006b, 1059). Regulation refers to the set up and execution of cooperation norms and standards within the network. It is thereby important to ensure that rewards and punishments cannot be executed for convenience (Möller 2006b, 1059). Evaluation finally refers to the assessment of all tasks of the business network management system as well as their assistance. The influential factors as well as the design of the value chain system effect the level of performance of the network. In this study we follow Möller's (2006b, 1053) suggestion of measuring success as the perceived level of achievement of business network objectives (Möller 2006b, 1053).

## HYPOTHESES

- The design of the value chain depends on the influential factors (structure hypotheses):
  - The higher the trust amongst the participants of the network the better the design of the value creation system.
  - The more distinct the participation in network the better the design of the value creation system.
  - The higher the strategic importance of the network for the network partners, the better the design of the value creation system.
- There is a mutual relationship between the value creation system tasks when designing the value chain (= value creation system hypotheses)
  - The better the selection for a network, the better the allocation.
  - The better the selection for a network, the better the regulation.
  - The better the allocation in a network, the better the regulation.
  - Selection, allocation and regulation are positively depending on the evaluation.
- The influential factors are affecting the performance level of the business network (direct performance hypotheses):
  - The higher the trust amongst the participants of the network, the higher the performance generated by the network.
  - The more distinct the participation in network, the higher the performance generated by the network.
  - The higher the strategic importance of the network for the network partners, the higher the performance generated by the network.
  - The better the regulation, the higher the performance generated by the network.
- The design of the value chain is affecting the performance level of the business network (indirect performance hypotheses):
  - The better the selection for a network, the higher the (indirect) performance generated by the network.
  - The better the allocation in a network, the higher the (indirect) performance generated by the network.
  - The better the evaluation, the higher the (indirect) performance generated by the network.



## **METHODOLOGY**

Our empirical study is according to Baumgarth and Evanschitzky (2009) or Evanschitzky et al. (2007) a mix of type 1 and type 2 replication of Möller's (2006b) study who examined the correlation between the influential factors, management system and success of business networks. The changes in our study refer to variations in the data analysis (different software, adaptation of the analysis method). Furthermore we focused on one particular industry, which was the maritime industry in the area of Bremen/Bremerhaven. We developed a questionnaire consisting of 27 closed questions (5-point-Likert-scales) for testing the hypotheses and 3 closed questions (nominal scale) for measuring the statistical information of the respondents. The population refers to 320 maritime companies that were listed in the industry catalogue of the Bremen Business Development Agency. All these companies were approached and the questionnaire was sent out to them. A total of 55 duly completed forms were analyzed (return rate of 17.2 %). The data was analyzed with SPSS 18.0. The majority of the analyzed companies belonged to the category of ship building companies or suppliers to ship builders (21; n=55). The remaining companies indicated the categories "maritime services" (18; n=55), "port economics and logistics" (10; n =55) and "maritime engineering and ship owners" (6; n=55). Three out of four respondents indicated to participate in a business network for more than five years, which can be considered as a long-term-partnership.

## **SELECTED RESULTS, DISCUSSION AND OUTLOOK**

Following Möller's (2006b) approach we condensed the individual items to the relevant constructs by indexing the individual mean values. The influential factors trust, participation and strategic importance show thereby a range of mean values between 3.07 and 3.71. This range was higher than the range of mean values of the value creation tasks selection, allocation and regulation that was between 2.6 and 2.9. Only the tasks of evaluation of the management function showed a higher mean value (3.3, n=55). Afterwards we correlated the constructs in order to identify a pattern in the relationship using Pearson's r. We were able to identify weak correlations between participation, evaluation, selection and the performance level as well as between trust and selection, selection and allocation, selection and regulation. Moderate correlation was identified between strategic importance, allocation, regulation and performance level as well as between selection and evaluation, evaluation and allocation and evaluation and regulation. These results pinpoint to the relation between the design of the value chain and the performance level of the business network. Additional Multiple regression analysis has shown that the influential factors (trust, participation and strategic importance) explain 26 % of the performance level of the business network. Participation as well as strategic importance have the strongest influence in this relationship. The management tasks (selection, allocation, regulation and evaluation) explain 37 % of the performance level of the business network. Allocation has thereby the strongest influence. Based on these results, we were not able to confirm our set of structure hypotheses as well as the hypothesis on the importance of trust on the performance level of the business networks. The other hypotheses received some or high support by our findings. Our findings although support the Möller's (2006a and 2006b) idea of measuring the performance level of business networks, even though we were not exactly following his methodological suggestions. Some of the differences between Möller's (2006a and 2006b) and our results may refer to the particularities of our sample, which was based in a specific industrial sector. Our respondents also indicated to be embedded in an industrial network setting for a long period of time. This may explain the lacking relationship between trust and the performance level, as this may be already internalized. In a next step, it would be interesting to examine what other factors may explain the performance level of industrial maritime business networks in the region. In order to increase external validity of our findings, we suggest examining other maritime industrial business networks in other regions.

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# SUEZ CANAL LOGISTICS HUB: COMPETITION AND CHALLENGES

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## ABSTRACT

Suez Canal is continuously developed to accommodate modern ships where the ships draft reach 66 feet. The Canal has four doubled zones with six bypasses with overall length 193.3 km. It is providing the shortest route between Europe and Far East in terms of distance, fuel consumption and operating costs. This allows the transit of ships in both directions and attracting more shipping lines and shippers. However, alternative routes to move trade from North West Europe to Far East have taken place including Panama Canal, Northern Sea Route (NSR) and Cape of Good Hope. Hence, the Egyptian government has recently set executive steps for a national project that aims at developing the Suez Canal zone to become one of the world's leading logistics hubs. Hub became in recent times essential for improving traffic as it provides shipping lines with adding value logistics activities and services. The purpose of this paper is to discuss how Suez Canal can be further developed as international hub to remain monopolistic position for world trade?

## KEYWORDS

Adding value logistics activities, logistics hub, Suez Canal competitive routes

## INTRODUCTION

The Suez Canal is an artificial sea-level waterway in Egypt, connecting the Mediterranean Sea and the Red Sea as shown in Figure 1. Since opening in 17<sup>th</sup> November 1869, it allows transportation by water between Europe and Asia without navigation around Africa. The northern terminus is Port Said and the southern terminus is Port Tawfiq at the city of Suez. When first built, the Canal was 26 ft deep. After multiple enlargements, the Canal is 66 ft deep. The Canal is a single lane with six passing places. It is the longest Canal in the world without locks; seawater flows freely through the Canal. The Canal is owned and maintained by the Suez Canal Authority (SCA) of Egypt. The accidents are almost nil compared with other waterways, and where navigation goes day and night. Geographically, it lies on a unique site where hosting 8% of the world sea-borne trade in 2012 with annually earning almost \$5.2 billion per year.

### Suez Canal Importance

The Suez Canal is considered to be the shortest route between the East and the West due to its unique geographic location. It plays an important role in serving international trade as it achieves a saving in distance, time, fuel consumption and ship operating costs. Table 1 shows for example the saving distance between main ports using Suez Canal route compared with Cape route.



Figure 1: Suez Canal

From	To	Distance		Saving	
		Mile	With nautical	In Miles	Percentage
		Canal	Cape		

Ras Tanura	Constanza	4144	12094	7950	66%
Jeddah	Piraeus	1320	11207	9887	88%
Singapore	Rotterdam	8288	11755	3647	29%

Table 1: Saving in distance between Suez Canal and Cape

Suez Canal is the longest canal in the world without locks. The width of the navigational channel is between 200 m and 210 m and ships of about 20 m draft can pass through the Canal. The Canal is liable to be widened and deepened when required, to cope with the development in ship sizes and tonnages. Table 2 shows the Canal characteristics.

Description	Unit	2012
Overall Length	Km	193.3
Doubled Parts Length	Km	80.5
Cross Sectional Area	m <sup>2</sup>	5200
Max. Permissible Draft	Feet	66
Max. Tonnage (DWT)	1000 tons	240

Table 2: Suez Canal characteristics

### Suez Canal and World Sea-borne Trade

Technological development and scientific research has led to a rapid growth in international trade and the exchange of products between countries (Siebert, 1999). The developed economies witness an expansion in imports and exports by 11.5% in volume terms, while the rest of the world increased by 16.5% (WTO, 2010). The demand for seaborne trade is derived from the demand for international trade (Lun et al., 2010). In fact, about 90% of world trade is transported by sea in volume terms and almost 80 % in value terms (Zouari and Khayech, 2011). The importance of Suez Canal is getting augmented with an increase in demand on maritime transport and world trade. The Canal has the capacity to accommodate up to 25,000 ships per year. In 2012, the Canal accounted for 8% of the world trade as shown in Table 3.

Years	World Trade (M.Ton)	Suez Canal Traffic		
		No. of Vessels	M.Ton	SC share %
2008	8238	21415	723.0	8.8
2009	7838	17228	559.2	7.1
2010	8591	17993	646.1	7.5
2011	8947	17799	691.8	7.7
2012	9297	17225	739.9	8.0

Table 3: World Sea-borne Trade Development and Suez Canal share (2003– 2012)

**Ship Type Distribution in Suez Canal (2011 – 2012)**

In 2012, there were 17,225 ships passed the Canal, compared with 17,799 ships passed the Canal in 2011, with reduction by -3.2 %. There was mainly a decrease in LNG ships by -26.1%, container ships by -11.8% and passenger ships by -10.4%. Figure 2 shows the ship type distribution passing the Canal in 2012.

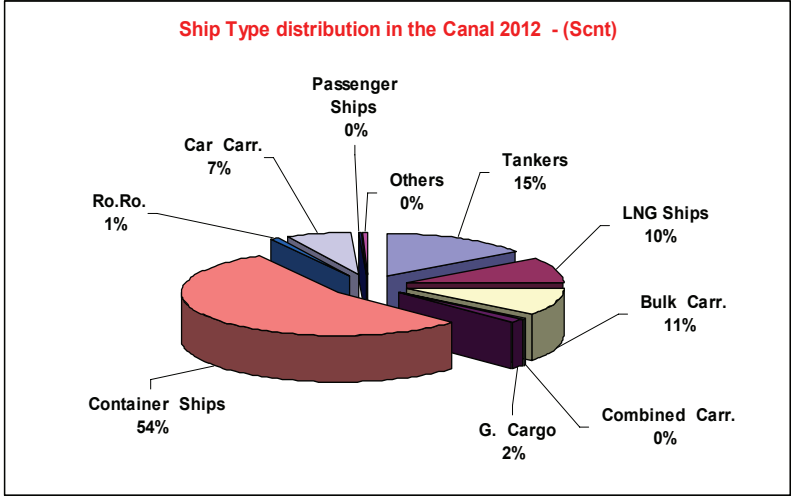


Figure 2: Ship Type Distribution Passing the Suez Canal in 2012

Suez Canal role in Asia-Europe trade lane diminishes by years due to high charges, security reasons caused by piracy acts and changes in world trade patterns. Findings conclude that challenge exists by changing economic geography in world trade such as growing new trade areas including South America and South Africa. The following section discusses the competitive routes facing Suez Canal.

However, with a reduction in number of total ships passing the Canal, there were more than 77.8 % of Europe-Far East container trade transiting Suez Canal in 2012, and more than 86.6% of Europe and Middle East/South Asia/Far East container trade transiting Suez Canal in the same year (SCA, 2013). Also, the container trade route between East Coast of North America and Far East through Suez Canal is a fast growing route with growth by 28.1% on average yearly (3.1 million TEU in 2012 compared to 0.7 million TEU in 2006) (SCA, 2013).

**A REVIEW of SUEZ CANAL COMPETITION**

A group of alternative routes are competing with Suez Canal. All alternative routes can be grouped into three groups including sea routes, road and rail routes and oil and gas pipelines (Galall, 2013). Firstly, the sea routes include Panama Canal after expansion (2015), Northern Sea Route and Cape Route. For Panama Canal after expansion in 2015, the draft will raise to 50 feet attracting most of Post-Panamax ships with total capacity of 12000 TUE. For Northern Sea Route (NSR), it is the shortest route between North Europe and Far-East. However, it is only seaworthy for four months per year and those ships passing this route cannot carry more than 20,000 tonnes. For Cape Route, Galall (2013) argued that this is an alternative route in case of closing Suez Canal rather than a competitive route.

Secondly, the road and rail routes include Eilat– Ashdod Rail Way and Euro-Asia Bridge. Eilat– Ashdod Rail Way relies on trucks for moving containers from Eilat to Ashdod and it takes from 6 to 12 hours. This will result in extra cost and time and it requires connected terminals in both ports. The second alternative route is the Euro-Asia Bridge that connects Rotterdam port with Liaynyngang in China passing through 30 countries, saving distance by 9000 Km.

Thirdly, the oil and gas pipelines include Eilat-Ashkelon pipelines that connects Ceyhan Port in Turkey with Eilat and Ashkelon pipeline in order to export Central Asian oil to Indian and China bypassing Suez Canal.

Notteboom (2011) claimed that the Suez Canal role in Asia-Europe trade lane diminishes by years and he recommended Cape route as a competitive alternative to the Suez route. He claimed that the first challenge appears in shifting piracy acts from Malacca to Gulf of Aden. An increase of these threats has led to increase the insurance fees. The second challenge exists that the Canal has a finite and full capacity that cannot accommodate future demand of transit vessels. The third challenge is presented in the presence of routing alternatives to the Canal, namely the Northern Sea Route, North South Land Corridor and the East-west Rail Corridor. The fourth challenge is that there are different routing alternatives for the trade traffic between USA and Asia, including US West coast ports and rail network and Panama Canal. The final challenge exists by changing economic geography in world trade such as growing new trade areas including South America and South Africa.

As competitive routing alternatives to Suez Canal, Schoyen and Brathen (2011) identified alternative routes to move from North West Europe to Far East, namely Panama Canal, NSR and Cape of Good Hope. Despite the navigation distance from West to East via Northern Sea Route (NSR) is shorter than Suez Canal by 40%, the NSR is suffering from uncertainty in schedule reliability that might fit tramp ships rather than liner shipping and seasonality where the ice-free season has increased to 129 days instead of 89 days (Rodrigues, 2008). However, they focused on tramp shipping rather than liner shipping. The focus was on bulk trade rather than other types of cargo. Also, they did not consider these challenges facing NSR such as requirement of powerful ice-breaker fleet, strong diesel electric vessels, a lack of ice-breaker capacity, high fees of ice-breaker, the fees are not linked with the actual services rendered, potential changes in the Arctic environment due to accidents and operations, and conflicts in coastal state regulation between Russia and Canada, USA and Norway (Ragner, 2008).

It can be concluded that there is a number of alternative routes facing Suez Canal since its opening in 1869. These routes place the Canal in competition for attracting sea-borne trade. Remaining as a competitive choice, Stopford (2009) identified five factors of product differentiation in shipping that is linked with route choice; price, speed, size, security and reliability.

## **RESEARCH PROBLEM**

The discussion of the previous section shows a number of qualitative conclusions on perceived competition to provide routing alternatives to the Suez Canal. The question rises in this paper is how *Suez Canal can be further developed as international hub to remain monopolistic position for world trade?*

## **SUEZ CANAL AND LOGISTICS HUB**

Logistics hub has different forms (Nam and Song, 2011). From the logistics perspective, it can be a distribution centre. From freight transport perspective, it can be a freight village (logistics node). From facility location perspective, it can be logistics zone (free trade zone). From maritime logistics, it is often referred to as a process of planning and managing the flow of cargo and information with ocean carriage being involved. Notteboom (2002) claimed that the maritime logistics hub is concerned with individual functions relating to sea transportation as well as an effective logistics flow as a systematic entity of the logistics integration system. Nam and Song (2011) explained that the maritime transport has three players namely; shipping companies, port operators including value adding services and freight forwarders. Huang (2008) pointed out that the criteria to be a hub is not throughput cargo rate but the transshipment cargo rate. The following section discusses the current and proposed value adding services at Suez Canal that leads to international logistics hub.

Transferring the Suez Canal region into an international Logistics Hub is based on developing six pillars namely, transport, trade, tourism, renewal energy, human development and industrial complexes. Three governorates are located alongside the Canal that can help in developing these pillars including Suez, Ismailia and Port Said governorates. In Suez, the Suez Canal Container Terminal is planning to provide modern handling and operating systems for all transiting vessels using advanced technology. In

Ismailia, three projects are proposed including dredging tunnel under the Canal, establishing the valley of technology and establishing industrial and logistical areas at West of the Canal. In Port Said, a construction of new quays at Port Said East Port is proposed with overall length 1200 m and width 500 m, accompanied with establishing double rail lines connecting the port with its hinterlands. The SCA aims to provide value adding logistics activities in these governorates. The following section reviews the current and proposed logistics activities.

### **Review of Current Value Adding Services at Suez Canal**

Suez Canal can be transferred from cargo gateway to a logistics hub. Optimising operations, interface with complex transport, improving performance, reducing customer lead times, reducing prices, offering a wide range of logistics activities, integrated with supply chain and reduce wastes are required leading to an international hub. The Suez Canal has currently a number of value-adding services (VAS) that helps to strength its competitive position.

Firstly, the Canal has two shipyards namely Port Said Shipyard (PSS) and Port Tawfik Shipyard (PTS). The PSS is a leading shipyard in Egypt and it has a unique strategic place at the northern entrance of Suez Canal giving it a great privilege to attract many transiting ships for repair purposes, building of different floating vessels, different ship types, dredgers and tugboats. On the other hand, PTS has a unique strategic place at the southern entrance of Suez Canal. PTS provides repairs and building of medium and small floating units.

Secondly, the Suez Canal is provided with a fleet of 12 multi-type dredgers, a fleet of 35 multi-type tugs ranging used for towing, salvage, fire-fighting and berthing of ships. Also, it is provided with a fleet of 35 cranes.

Thirdly, Suez Canal has seven affiliated companies in different fields to support all activities alongside the Canal. (1)The Canal Mooring and Lights company is responsible for mooring and unmooring of vessels transiting the Canal. (2)The Canal Naval Construction company is specialised in building, repairing floating unit, ship modifications, petroleum service, medium size engine repairing and ship scraping. (3) The Port Said Engineering Works company is specialised in repairing and building small motor vessels and tugs. (4)The Canal Rope company is the biggest producer in Middle East for all kind of ropes and twines natural or synthetic and woven bags. (5)The Canal Harbour and Great Projects company is specialised in Marine Works and in Quarrying. (6)Temsah Shipbuilding company is specialised in shipbuilding, ship repairs, operation and maintenance of all kinds of auxiliary ships and water desalination plant. (7)Suez Shipyard company is specialised in ships repair, shipbuilding, steel structure, pipe lines, tanks, marine services and repair dredging equipment.

### **Proposed Value Adding Projects Leading into International Hub**

The hinterland of the Suez Canal region is relevant to accommodate new value adding projects, leading to be one of the most successful logistics areas of the world. Firstly, the Cold Logistic Park project is proposed to support the cold chain trade transiting the Suez Canal (Kotait, 2013). The project offers the perishables industry access to growing markets in the Middle East, high quality and cost effective trans-shipment, consolidation, and storage, packing and distribution activities. It is proposed to establish Container Park with full cold chain facilities.

Secondly, another project is applying the River Information Services (RIS) for logistics purposes (Gehlhaar, 2013). RIS is an intelligent IT solution that can assist SCA in their daily operations. RIS's objective is improving the integration of inland waterway transport through the Suez Canal into intermodal chains. It is not only a classical information provision, but it is also a Tailor-made proactive information services following the approach of Supply Chain Event Management (SCEM). Also, RIS system aims to integrate terminals alongside the Suez Canal in order to align the processes between sea ports, inland waterway transport and inland ports.

Thirdly, new container hub ports are emerging in the Suez Canal. The Suez Canal Container Terminal is located in Port Said, at the northern tip of the Canal, handling 3.1

m TEU in 2011. It includes a series of free zone areas, with planning to establish logistics and distribution centres in future. Sokhna Port is another container hub that is located in southern entrance of the Canal. It handled 0.6 m TEU in 2011 with future expansion in capacity.

Fourthly, the Establishment of Sinai Canal is recently proposed and discussed (Kamel, 2013). The proposed Canal aims to link Mediterranean Sea with Aqaba gulf, in parallel to Suez Canal. It aims to develop Sinai Peninsula and attracting more investment in logistics and adding value activities such as production, storage and transshipment. There are key ports that located in North and South Sinai that can play important role in developing the traffic in the proposed Canal, including Arish port in Northern Sinai and Taba Port in Southern Sinai. Three logistics centres are proposed to be established alongside the Canal. One centre to be located in the West of the Canal for building and repairing all types of ships. The second centre is for storing and re-exports purposes, supporting transshipment industry. The third centre is for production projects. Agricultural hinterlands are proposed in all centres. Fifthly, a proposed plan up to 2020 has been set by the Egyptian government for establishing a set of bridges and tunnels crossing the Suez Canal. For example, Ferdan Bridge is proposed to be the longest movable bridge in the world. Salam Bridge is for 5.9 Km enhancing the flow of cargo and passengers movement. Ismailia tunnel is proposed for 0.9 Km to link both sides of the Canal. A railway lines are proposed for 1200 m crossing the Canal. Also, it is proposed to establish a complete separate entity, a regulatory body, to manage and operate the Suez Canal Hub. Its responsibility is to deal with all involved ministries and agencies in Egypt & abroad, applying the international standards. It is suggested to apply non-bureaucratic procedures and to establish three sub entities in each zone (Port Said, Ismailia and Suez). It is proposed that this body would be responsible for organizing competition and Preventing monopoly, improving proficiency, increasing productivity, preparing human resources with required skills, Managing commercial conflicts and disputes and attracting investments. Finally, transferring Suez Canal from cargo gateway to international hub is a future requirement to accommodate the expected growth of China-NAAC container TEU trade to 14.3 m TEU in 2030 compared to 4.1 m TEU in 2010 (Ghonima, 2013). Presently the major segment of this traffic move via the Panama Canal. A much smaller portion, move via the Suez Canal, mostly to U.S Ports. Potential future diversion of 1.2 m TEU to the Canadian Atlantic Port of Halifax via the Suez corridor could develop due to water depth and the ability to develop incremental and terminal capacity to efficiently handle SPPX vessels.

### **DIFFICULTIES FACING THE DEVELOPMENT OF THE SUEZ CANAL HUB**

For remaining a monopolistic position in sea-borne trade, there is a need to develop the Suez Canal region. This will help to attract more shipping lines and shippers through providing value adding logistics activities.

However, the development process is facing many challenges that can be summarised as follows: (1) more than 50% of the region are difficult development areas according to the nature of topographic of Sinai as shown in Figure 3. (2) The region is suffering the lack of many basic services such as education, health care, trade and the absence of industries. (3) Urban problems caused by unbalance between population growth and population areas. (4) Poor communication and links between the Eastern and Western Banks of the Canal. (5) Peace agreement's conditions make the region is not attractive for investment and limit the possibilities of the exploitation of the region. (6) Difficulty to influence the demographic variables that are related to religious values and social and environmental habits, which cannot be changes. Multiple cultures make habits fundamentalist restrictions on development. (7) Huge investments are needed to meet the requirement of the region development. Most financial institutions, whether local or international, elude the required funding. (8) The population in the Canal region is about 9 million, where the unemployment rate is 9.7% in 2012. The following section provides some suggestions to cope with these difficulties.



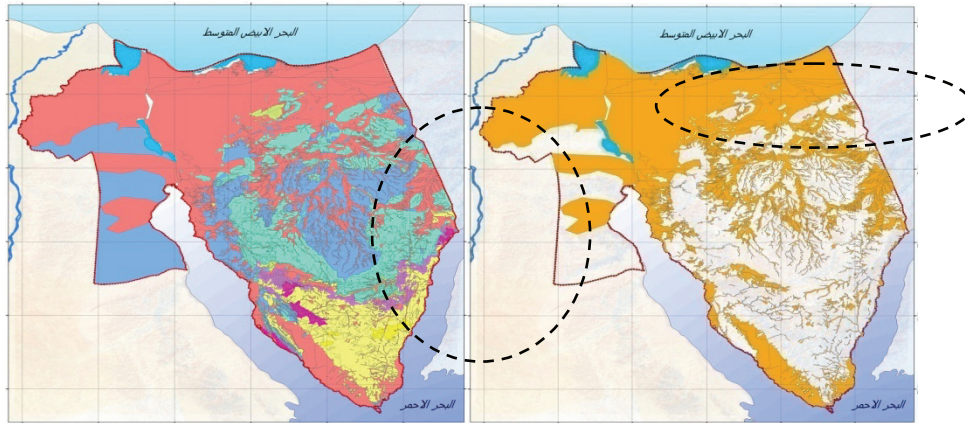


Figure 3: The Topographic Nature of Sinai

### RECOMMENDATIONS

Suggestions are proposed to be carried out in the future. (1) It is recommended to deep the Canal in future to 72 feet in order to be able to accommodate maximum capacity of 340,000 DWT. (2) Also, most the Canal is limited to a single lane of traffic. Thus, it is recommended to deep the Canal's six bypasses as this will allow transit of ships in both directions. (3) Reviewing the competitive pricing policies applied by other competitive routes is suggested. (4) Increasing the national projects in the region to attract more investment. (5) Re-distribution and push the population onto remote areas in the region. (6) Focus on the region's competitive advantage is required in the fields of energy production and tourism. (7) Raise the standard of living and household income. (8) Six governorates can play an important role in developing the Suez region, including Sharqia, Ismailia, Port Said, Suez, North Sinai and South Sinai. Coordination and integration between these governorates are highly required.

### CONCLUSION

Suez Canal has a competitive advantage facing exiting and developing alterative and competitive routes where all types of ships with maximum capacity of 240,000 DWT and 66 feet draft can pass the Canal. Pricing policy applied by SCA plays an indispensable role in attracting more ships. Difficulties are existing facing the development of the Suez Canal region. However, the Canal has value adding services that can be expanded to cope with an increase in sea-borne trade. Proposed value adding services are discussed to transfer the Suez region into international logistics hub.

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# LEAD-TIME INDICATORS IN THE ECONOMICS OF EUROPEAN UNION SHIPBUILDING

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## INTRODUCTION

The shipping sector is a highly capital intensive industry. A ship functions on two levels in shipping markets: firstly, it is an asset in the capital market. The sale of one merchant ship is a large capital transaction and involves generally millions of US dollars. Secondly, a ship contributes to the supply of carrying capacity in the freight market. In most cases, ship-owners do not invest ships for speculative purpose; they focus more on the future payoff by chartering out ships in the freight market. To choose the right time to build new ships is essential under these circumstances. The duration from order to final delivery may take two years or longer. The market situation when a ship is delivered can be completely different from when it is ordered. In this sense, the lead-time between ordering and delivery makes the shipping industry highly volatile, or risky, in nature.

The 'time lag' issue has been a focus of study in maritime economics. The focus has been more on descriptive aspects such as directional causality relationships, i.e. Kavussanos and Nomikos (2003) and Kavussanos and Visvikis (2004) on spot and future markets; and lead-lag relationships, i.e. Xu et al (2011) on freight and shipbuilding markets. The lead-lag relationship between two markets indicates how fast one market reflects information relative to the other and how well the two markets are linked. However, the quantification of the 'time lag' is left unexamined, due to the fact that the lead-times at a macro level are normally difficult to collect or estimate. This paper aims to develop a method to determine shipbuilding lead-times and to use the estimated lead-times in econometric modelling. In doing so the paper

- Applies Little's Law (2011) to 6 year dataset for European Union (EU) shipbuilding to estimate lead-times.
- Conducts panel data analysis of secondary data to investigate the indicators of lead-times for EU shipbuilding.

## LITERATURE REVIEW

### Lead-times and their reduction in operations management

It is frequently posited that total cycle time compression (TCTC) is an effective way of gaining a competitive edge (Towill, 1996). Protracted and variable lead-times can lead to increased safety stock and suboptimal re-order points across the supply chain (Bagchi et al., 1986). Over-reactions, unnecessary interventions, second guessing, mistrust and distorted information flows are also likely to ensue (Childerhouse and Towill, 2004). The original exposition of the central role played by TCTC in enabling more efficient and effective supply chains occurred some two decades ago via the appearance of a cluster of seminal publications. These included Stalk and Hout (1990), Thomas (1990), and Scott and Westbrook (1991). The first named detailed a range of their "five rules of thumb" relevant to supply chain design and operation. The second emphasised the need to utilise the concept of ultimate performance as the on-going target to meet, with each improvement gathered momentum in delivering benefit. "Halving the Gap Every Two Years" became a slogan to summarise the expectancy of continuous improvement. Thomas (1990) was also noteworthy for highlighting the necessity to reduce process variance synchronously with compressing cycle times. This was later supported by Bozarth and Chapman (1996), who argue for the importance of variance control in TCTC, and the importance of applying this logic to multiple processes.

Bagchi et al. (1986) argue that it is important for managers to keep historical records of lead-times to enable analysis and understanding. Later research relating to TCTC appeared in Towill (1996), Hum and Sim (1996), relating to production applications, and Towill (2003), relating to construction applications. The latter concluded that a 40% reduction in project time can lead to a 25% reduction in total work undertaken and costs. In particular, procurement and the competitive bidding, as well as the design stage have been highlighted as being time bottlenecks for project based supply chains (Elfving et al., 2005; Gosling et al., 2007).

**Lead-times in the ship building industry**

A new ship needs to be designed, constructed and commissioned before coming into service. A shipbuilding project involves several companies and the roles of such companies may change from contract to contract. A typical project involves a ship-owner, a ship designer, a shipyard, dozens of main equipment suppliers and hundreds of minor other suppliers. The main project processes include tendering, engineering, procurement, production and commissioning as shown in the Figure 1.

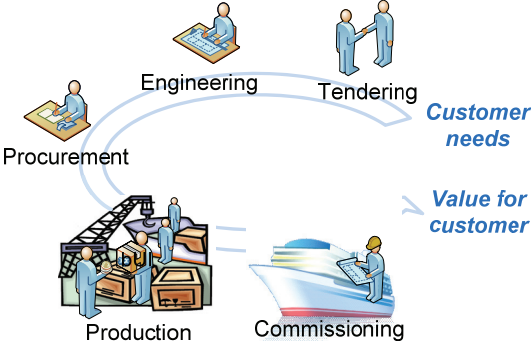


Figure 1. Main shipbuilding processes

This whole process can typically take a couple of years and hence shipbuilding decisions are inherently risky and wrong timing can turn a handsome expected profit into heavy losses. An example of typical value-add lead-times for an off-shore vessel is shown in Figure 2. The time lags between ordering and delivery make booms and recessions in shipbuilding more pronounced leading to cyclical behaviour (Stopford, 2009), and the cyclical nature of shipping market is what results in investment risk. During a turbulent period of financial uncertainty, in order to mitigate the risk, ship investors either want to cancel the orders or put off the delivery dates, which pushes the lead-times ever higher.

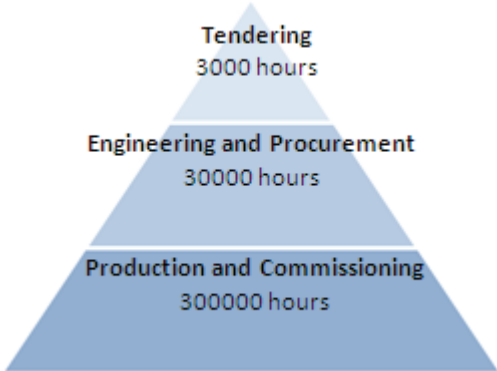


Figure 2. Typical lead-times in value adding activities for an offshore supply vessel

In this sense, we are motivated to study the attributes that impact on lead-time and the economic ramifications of increasing or reducing lead-times. We should note that lead-time compression in shipbuilding could be traced back hundreds of years when, in the 16th century, the Venetian *assenalotti* successfully compressed the cycle time of war galleys production to a single day (Towill et al., 2000).

## Little's Law

Little's Law deals with queuing systems, consisting of discrete items that arrive, at some rate, into the system and join one or more queues. These items are eventually serviced and exit in a stream of departures (Little, 2011). Little's Law has been established and developed over 50 years and it is "especially handy for 'back of the envelope' calculations" (Little and Graves, 2008). However, its application is only evident in a few empirical studies such as Georgantzis (2003) who applies it to the Cypriot hotel industry and Klassen and Menor (2007) who apply it to Canadian industry-level data. Other authors, such as Gormen et al (2009) and Rajagopalan and Malhortra (2001), merely mention it, though neither is in a maritime context. Klassen and Mellor (2007) pointed out Little's Law's usefulness in its flexibility in determining measurements of cycle-time and management of inventory turns. Despite its simplicity Little's Law has never been applied in the shipbuilding industry.

## METHOD

### Data description

In this study the data set contains information of 14 major shipbuilding countries in Europe. Table 1 shows the 14 countries and the order books received by each country in 2010. Our data set is annually based and covers the period from 2004 to 2010. The data sources we use in this study are from the Community of European Shipyards' Associations (CESA) annual reports, Clarkson's Shipping Intelligence Network (CSIN), Organisation for Economic Co-operation and Development (OECD) statistics and World Development Indicators (WDI) from the World Bank Group (WBG).

Country	Orderbook in CGT	Country	Orderbook in CGT
GERMANY	1537939	FRANCE	294594
ITALY	1085688	FINLAND	148691
NETHERLANDS	897879	POLAND	117592
ROMANIA	656860	DENMARK	100527
SPAIN	549963	PORTUGAL	14000
NORWAY	517793	UNITED KINGDOM	5000
CROATIA	510607	GREECE	0

Table 1. Orderbooks by country of build (2010)

The study employs a two-step model specification, which is outlined in Figure 3. The first step is the measurement of lead-time through an application of Little's Law (Little, 2011). We collect secondary data on order-books, new orders and cancellations from 14 European countries ranging from 2004-2010, all the data are annually based in numbers. We test and evaluate the application of Little's Law in estimating lead-times ( $W$ ) in shipbuilding through two types of model specification.

The second step is a Panel Data Analysis of the relationship between the estimated lead-times and a series of economic variables: Order-books received in Compensated Gross Tonnage (CGT), representing the amount of work that is necessary to build a given ship; Trade Volume (TRADE), representing the demand of shipbuilding; CGT divided by direct workforce involved in shipbuilding (CGT/WORKFORCE), representing the shipbuilding productivity; Clarksea Index (CLARKSEA), representing the freight market level; and Gross Domestic Product (GDP), serving as the control variable. We further add two types of specialised vessels, Chemical carriers (CHEMICAL) and General cargo ships (GENERAL), to reflect how the lead-time can be affected by ship type.

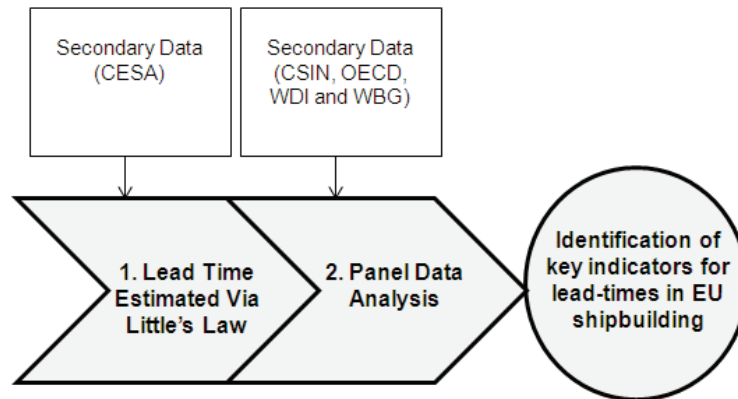


Figure 3. Visualisation of method applied

### Application of Little's law – estimating lead-time in shipbuilding

Little's Law says that the average number of items in a system,  $L$ , equals the average arrival rate of items in the system,  $\lambda$  multiplied by the average waiting time of an item in the system,  $W$ :

$$L = \lambda W \quad (1)$$

This can be reformulated for the purpose of lead-time calculations; the average waiting time is the focus of the following:

$$W = L / \lambda \quad (2)$$

This rearranged formula can be used to calculate shipbuilding lead-time,  $W$ , while  $L$  denotes the orderbook currently received, and  $\lambda$  denotes new orders or new orders deducted less cancellations during the time period. We calculate the lead-time for each of the 14 countries.

### Panel data analysis – econometric modelling of lead-time in shipbuilding

In this study, the data is collected from both cross-sectional units and over time, i.e. 14 European countries over the period from 2004 to 2010. This type of data is known as panel data. The fundamental advantage of a panel data set over a cross section is that it allows great flexibility in modelling differences in behaviour across individuals over time (William, 2008). The basic framework for this discussion is a regression model in equation (3):

$$y_{it} = x'_{it}\beta + z'_i\alpha + \varepsilon_{it} \quad (3)$$

Where  $x_{it}$  represents the regressors,  $z'_i\alpha$  represents the heterogeneity or individual effect where  $z_i$  contains a constant term and a set of individual variables or group specific variables. In order to determine the differences across groups, an F-test is used to test the hypothesis that the constant terms are all equal. The null hypothesis is: there is no difference among groups (Pooled Regression). The alternative hypothesis is: there is a difference among groups (Fixed Effects). The null hypothesis of no fixed effect cannot be rejected in this study thus the pooled regression is chosen<sup>1</sup>.

In the pooled regression model,  $z_i$  contains only a constant term, the ordinary least squares method provides consistent and efficient estimates of the common  $\alpha$  and the slope vector  $\beta$ . This means the relationship between the dependent and explanatory

<sup>1</sup> The F-ratio used for this test is denoted as  $F(n-1, nT-n-K) = \frac{(R^2_{Fixed} - R^2_{Pooled})/(n-1)}{(1 - R^2_{Fixed})/(nT-n-K)}$ , where subscripts 'Fixed' and 'Pooled' indicate the  $R^2$  for the fixed effects and pooled regression models.

variables is governed by the same regression coefficients for all cross-sectional unit  $i$  ( $=1, 2, \dots, N$ ) and time-period  $t$  ( $=1, 2, \dots, T$ ). The model used in this study follows the basic structure of equation (4).

$$y_{it} = x'_{it}\beta + \alpha + \varepsilon_{it} \tag{4}$$

In this study, we apply a Panel Data Analysis of the relationship between the estimated shipbuilding lead-times from the first step and a series of economic variables, reflecting the supply and demand of shipbuilding, shipyard productivity and freight market level. A number of typical specialised vessels are also chosen to reflect how ship types can affect the lead-time.

## FINDINGS

### Little’s Law lead-time estimation – sample results

In Figure 4 we exhibit the estimated average lead-times of European shipyards in our dataset, while Figure 5 shows those estimated lead-times for France and the Netherlands.

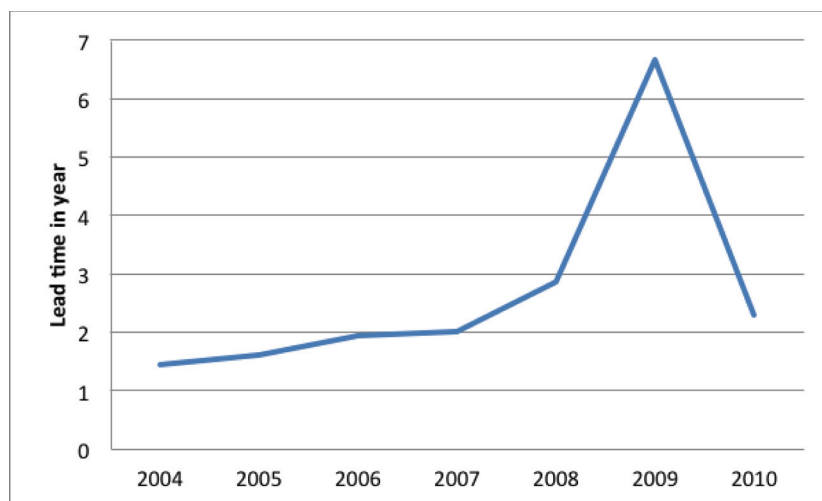


Figure 4. Estimated average lead-time at European shipyards (2004- 2010)

The estimated average lead-time at European shipyards was below 2 years during the boom years between 2004 and 2008 but exhibited a drastic increase during the recession period 2008 - 2009. Both France and the Netherlands exhibit a similar trend with a low lead-time, again below 2 years, during the boom years between 2004 and 2008 and then a drastic increase during the recession years between 2008 and 2009. In 2010 a recovery is indicated as all lead-times fall back to below 2 years again.

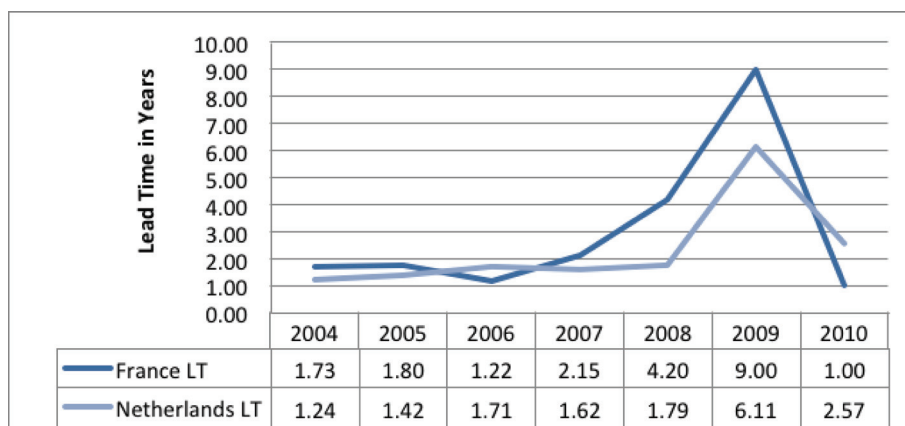


Figure 5. Estimated average lead-time for France and the Netherlands (2004-2010)

### Panel data interpretation

The panel data analysis analyses the estimated lead-times from step one as a function of work load (CGT), productivity (CGT/WORKFORCE), trade volume (CLARKSEA), freight rate (TRADE) and GDP, as shown by equation (5).

$$W = C + C_1 \bullet CGT + C_2 \bullet (CGT/WORKFORCE) + C_3 \bullet CLARKSEA + C_4 \bullet TRADE + C_5 \bullet GENERAL + C_6 \bullet CHEMICAL + C_7 \bullet GDP \quad (5)$$

Table 2 shows the results of our panel data analysis. The positive sign of CGT indicates a positive impact of shipbuilding capacity on  $W$ . It implies a larger shipbuilding workload leads to a longer lead-time. In the mean time, CGT/WORKFORCE, CLARKSEA and TRADE are negatively related to  $W$ . CGT/WORKFORCE represents the shipbuilding productivity: the more efficient the shipbuilding activity is, the shorter it takes to deliver the vessel.

Dependent Variable: LOG(W)  
Method: Panel Least Squares  
Sample: 2004 2010

Independent Variables	Coefficient	Std. Error	t-Statistic	Prob.
LOG(CGT)	6.106864	1.954600	3.124354	0.0025
LOG(CGT/WORKFORCE)	-6.076015	1.961348	-3.097877	0.0027
LOG(CLARKSEA)	-2.106409	0.388204	-5.426032	0.0000
LOG(TRADE)	-0.267582	0.103011	-2.597615	0.0112
LOG(GENERAL)	1.304459	0.278898	4.677192	0.0000
LOG(CHEMICAL)	-1.581684	0.429432	-3.683205	0.0004
LOG(GDP)	0.239455	0.116074	2.062957	0.0425
C	-46.09225	17.61933	-2.616005	0.0107
R-squared	0.461907	Mean dependent var		0.959872
Adjusted R-squared	0.412989	S.D. dependent var		0.698515
S.E. of regression	0.535179	Akaike info criterion		1.676957
Sum squared resid	22.05404	Schwarz criterion		1.906854
Log likelihood	-63.27068	Hannan-Quinn criter.		1.769428
F-statistic	9.442563	Durbin-Watson stat		1.610853
Prob(F-statistic)	0.000000			

Table 2. Panel data analysis results

The negative sign of CLARKSEA, indicating the freight rate level, shows ship-owners are willing to invest in new ships and value short delivery time when they confide in a profitable freight market. Trade volume, TRADE, represents the demand of sea transport services, a high demand of sea transport services implies the expectation of a high return in the freight market, thus encourages quick deliveries of new ships and shorter lead-times. Furthermore, we explore the different patterns of ship types exhibited in shipbuilding and vessel deliveries. The positive sign of GENERAL (general cargo ships) and negative sign of CHEMICAL (chemical carriers) show the impact of ship sizes on vessel deliveries.

## DISCUSSIONS AND CONCLUSIONS

Figure 5 shows a causal diagram summarising the findings of the research. The diagram highlights the influence of the variable studied on ship-building lead-time for the data set studied. 'S' indicates the variable influence, in the direction of the arrow, is in the same direction, while 'O' indicates the opposite direction.



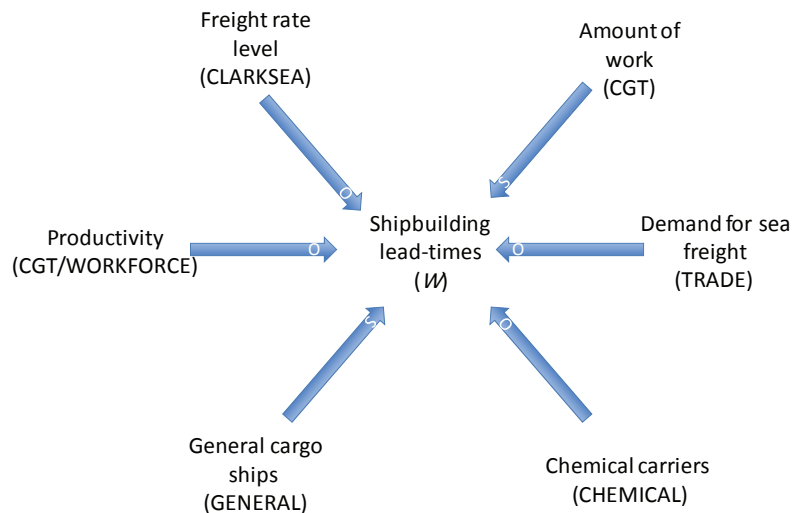


Figure 5: Causal loops diagram of lead-time indicators

This paper has investigated lead-time indicators by, firstly, applying Little's Law to a six year dataset for EU shipbuilding to estimate lead-times, and secondly, undertaking a panel data analysis of secondary data. A contribution is made by developing and applying a two-stage method. In doing so, we have examined at a macro level the shipbuilding 'time lag', which is normally difficult to collect or estimate. The first part of our study, using Little's Law to estimate lead-times, gives insight into average lead-times from 2004 to 2011. This allows us to observe the trends over the recent recession, showing a marked increase in lead-times during the height of the recession. This is possibly due to customers either cancelling their orders or delaying the acceptance of orders. In the former case such cancellations are made while shipbuilding is in progress and therefore the shipbuilding yards aim to complete the ship and sell speculatively or find a new customer before completion in so as to ensure a degree of customisation. In the latter case the shipbuilder retains the completed ship until the customer requests delivery. In both cases, the ship remains in the yard's order book and hence the estimated lead-time is extended.

The second part of our study, the panel data analysis, gives insight into the indicators of lead-times. Both the freight rate level and the demand for sea freight are end market place indicators. Hence, customers see the opportunity for the utilisation of new ships, wherefore they can charge more for freight and the demand for freight movements increases. Operational shipbuilding indicators are given by productivity and amount of work measures. As operational efficiency increases we see a reduction in lead-time, while as the amount of work per ship increases the lead-times increase. The two remaining indicators, indicative of the design content of a ship type, are related to whether a ship is for general cargo or specialist, in our case, chemical carriers. One might expect a more specialist ship to have a greater degree of complexity and hence lead-times may be expected to increase, in contrasts to a more standard type. But as the analysis shows the opposite is indicated and may be due to the size of ship, and hence related to work content which is given by gross tonnage rather than any indicator of complexity. This aspect of the research requires further study and the need to explore new indicators that combine complexity with amount of work.

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# **REDUCTION OF BOTH COST AND CO<sub>2</sub> EMISSIONS IN THE VEHICLE ROUTING AND CARGO ALLOCATION PROBLEM**

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## **ABSTRACT**

Cargo carriers are obligated to reduce the CO<sub>2</sub> emissions from cargo transportation activities. In our previous work, we attached great importance to CO<sub>2</sub> emissions and proposed a method to solve the vehicle routing and cargo allocation problem with minimum CO<sub>2</sub> emissions. However, cargo carriers tend to focus on reducing cargo transportation costs rather than CO<sub>2</sub> emissions. The purpose of this paper is to reduce both CO<sub>2</sub> emissions and transportation costs for truck delivery of cargo with various weights to two or more delivery points. We define a vehicle routing and cargo allocation problem with minimum cost and minimum CO<sub>2</sub> emissions and propose a method to solve this problem. Experiments were conducted using both synthetic data and actual data from a cargo carrier in Japan. The results validate the utility of the proposed method.

## **1. INTRODUCTION**

Cargo carriers are obligated to reduce the CO<sub>2</sub> emissions from their cargo transportation activities. They do so by using eco-friendly trucks and exploiting the improved convenience of railroad transport and maritime transport, etc., as policies in each transport mode. In addition, they work on modal shifts and increase in the number of mixed-loading trucks, etc., as policies for improving the physical distribution system. In addition to implementing these policies, it is indispensable to consider how to determine the route with the minimum CO<sub>2</sub> emissions.

The vehicle routing problem is used to improve efficiency for delivering cargo from a depot to two or more delivery points. The objective is typically to minimize the transport distance. Some vehicle routing problems, such as the time window constrained problem (Solomon, 1988), have been defined, and various algorithms using mathematical programming (Laporte, 1992; Baker, 2003) and heuristics (Chiang, 1997) have been proposed to solve these problems. However, none of the work to date is applicable to minimizing CO<sub>2</sub> emissions. When delivering cargos with different weights to various delivery points, the shortest route does not necessarily minimize CO<sub>2</sub> emissions. Besides, CO<sub>2</sub> emissions could be decreased by assigning some cargos to a different series of delivery operations or delivering them with different trucks.

In our previous work, we attached great importance to CO<sub>2</sub> emissions and proposed a method to solve the vehicle routing and cargo allocation problem with minimum CO<sub>2</sub> emissions (Otani, 2011; Otani, 2012). To make the approach more practical, however, actual field conditions should be taken into consideration when setting constraints and the objective function. Otani et al. (Otani, 2012) introduced two schemes into their method in order to avoid increasing the time required to complete all deliveries. One of the schemes took the number of trucks and the variation in their maximum loads into consideration. The other scheme avoided unused trucks and the use of trucks on two or more delivery routes. This approach is effective for cargo carriers that contract deliveries with senders and deliver them by themselves, but is not applicable for cargo carriers that entrust all of the deliveries to some subcontractors. At present, most of cargo carriers entrust subcontractors with deliveries. It is necessary, therefore, to further develop the method to determine cargo allocation and delivery routes for both the cargo carrier and any subcontractors.

The outsourcing fee for cargo deliveries is based on many variables, such as the number of cargos, total weight of cargos, total volume of cargos, number of charter trucks available, time required to charter trucks, transport distance, and so on. The charter fee of a truck depends on the maximum load and chartered period, but two small trucks cost more than a single large truck. To reduce the cost, cargo carriers typically allocate cargos to subcontractors to minimize the number of trucks required. Labour costs and fuel costs, which are directly linked to the number of trucks and CO<sub>2</sub> emissions, respectively, constitute the greatest transportation costs for the subcontractor. Subcontractors are

able to reduce their costs by optimizing delivery routes to minimize CO<sub>2</sub> emissions. This leads eco-friendly physical distribution and associates their company image with eco-friendly operations.

In this paper, a vehicle routing and cargo allocation problem with minimum cost and minimum CO<sub>2</sub> Emissions (VRCAP-MCMCE) is defined that takes into consideration not only the outsourcing fee for the cargo carrier, but also the transportation costs for the subcontractors. In addition, a method is proposed to solve this problem. Optimal routes for subcontractors are heavily influenced by the cargo allocation for the cargo carrier. In our proposed method, an evaluation of each subcontractor's delivery route is fed back to the cargo allocation for the cargo carrier. Symbiotic evolution (Moriarty, 1996), a kind of evolutionary computation represented by the genetic algorithm, is used to search for the optimal delivery route. VRCAP-MCMCE is very similar to the vehicle routing problem that seeks the shortest route, and is represented by the traveling salesman problem (TSP). However, values of the objective function in VRCAP-MCMCE are more heavily dependent on the route than in TSP. Symbiotic evolution is appropriate for tasks like VRCAP-MCMCE because of its inherent characteristics.

## 2. DEFINITION OF VRCAP-MCMCE

### 2.1 Calculation method for CO<sub>2</sub> emissions

The revised Energy Conservation Law in Japan includes three calculation methods to measure and manage CO<sub>2</sub> emissions during transportation: the fuel consumption method, the fuel efficiency method, and the revised ton-kilometer method. The most accurate method is the fuel consumption method, which calculates CO<sub>2</sub> emissions according to fuel consumption. However, it is impossible for drivers to know the actual fuel consumption prior to transportation, thus they cannot use the fuel consumption method to plan their delivery route. Therefore, either the fuel efficiency method or revised ton-kilometer method is used as an alternative. When considering the load efficiency of a truck, the CO<sub>2</sub> emission  $e$  (t-CO<sub>2</sub>) is calculated in the revised ton-kilometer method as:

$$e = w \times d \times y \times a \times 10^{-3} \quad (1)$$

where  $w$  (t) is the cargo weight,  $d$  (km) is the transport distance,  $y$  (L/t•km) is the amount of fuel consumption per ton-kilometer, and  $a$  (t-CO<sub>2</sub>/kL) is the CO<sub>2</sub> emission factor, which is defined by fuel type in the bulletin of the Energy Conservation Law. The value of  $a$  for light oil is 2.62 t-CO<sub>2</sub>/kL. The 66th bulletin of the Japanese Ministry of Economy, Trade and Industry states that the value of  $y$  for a truck using light oil should be calculated as:

$$\ln y = 2.71 - 0.812 \ln \frac{x}{100} - 0.654 \ln z \quad (2)$$

where  $z$  (kg) is the maximum load of the truck and  $x$  (%) is the load efficiency. When the load efficiency is less than 10%,  $y$  is calculated using 10% as  $x$ .

### 2.2 Propositions

VRCAP-MCMCE is defined using the following propositions.

- ◆ The goal is to find the route and cargo allocation that results in the minimum CO<sub>2</sub> emission, without increasing the outsourcing fee for the cargo carrier.
- ◆ Deliveries will be made to two or more delivery points. The cargo weight may differ between delivery points.
- ◆ CO<sub>2</sub> emissions are calculated with the revised ton-kilometer method, i.e., using equations (1) and (2). To consider the case of empty loads, a weighted average cargo weight by the transport distance is calculated and used as  $w$ .
- ◆ The cargo carrier contracts cargo deliveries with senders, and entrusts the deliveries to one or more subcontractors.
- ◆ The outsourcing fee is based on the cost of chartering trucks.
- ◆ The cost to charter a single truck depends on the maximum load of the truck. Larger trucks are more expensive, but two small trucks are more expensive than a single large truck. The standard fee is about 30,000 JPY for a 2 ton truck, 40,000 JPY for a 4 ton truck, and 50,000 JPY for a 10 ton truck.
- ◆ All cargos are able to be delivered without using any truck more than once.

- Delivery points are divided into some groups called units. A series of delivery operations is performed for every unit. In other words, a truck is assigned and a corresponding route is determined for each unit.
- All routes start and finish at a depot. Trucks do not return to a depot during delivery operations.
- The following data are given
  - ✓ The total number of the trucks owned by subcontractors and the variation in the maximum loads of those trucks
  - ✓ Weight of cargo to be delivered to each delivery point
  - ✓ Symmetrical transport distances between all pairs of delivery points
  - ✓ Symmetrical transport distances between all delivery points and the depot

### 2.3 Notations

The number of delivery points is denoted by  $N$ , and the delivery points are numbered from 1 to  $N$ . The depot is numbered 0. In this paper, the numbers that identify delivery points are called "dpIDs." The number of units is denoted by  $M$ , and the  $i$ th unit is denoted by  $U_i$ . The number of delivery points in  $U_i$  is denoted by  $N_i$ . A route for  $U_i$  is denoted by a vector  $\mathbf{r}_i$ .

$$\mathbf{r}_i = (r_i[0], r_i[1], \dots, r_i[N_i], r_i[N_i+1]) \quad (3)$$

where  $r_i[j]$  is the dpID of the  $j$ th visited delivery point in  $U_i$ . As the depot is both the starting and the terminal points of the route,  $r_i[0]$  and  $r_i[N_i+1]$  are set to 0. The cargo weight to be delivered to delivery point  $n$  is denoted by  $w_n$  ( $1 \leq n \leq N_i$ ). The total weight of all cargos on the truck being transported from  $r_i[k-1]$  to  $r_i[k]$  is denoted by  $W_i[k]$  ( $1 \leq k \leq N_i+1$ ), as defined in equation (4).

$$W_i[k] = \sum_{n \in U_i} w_n - \sum_{j=1}^{k-1} w_{r_i[j]} \quad (4)$$

The transport distance between delivery points  $i$  and  $j$  is denoted by  $d_{i,j}$  ( $0 \leq i \leq N$ ,  $0 \leq j \leq N$ ). All  $d_{i,i}$  are set to 0. The total transport distance  $d_i$  for  $U_i$ , the weighted average cargo weight  $w_i$  for  $U_i$ , and the amount of fuel consumption per ton-kilometer  $y_i$  for  $U_i$  are respectively calculated as follows:

$$d_i = \sum_{j=1}^{N_i+1} d_{r_i[j-1], r_i[j]} \quad (5)$$

$$w_i = \frac{1}{d_i} \sum_{k=1}^{N_i} W_i[k] \times d_{r_i[k-1], r_i[k]} \quad (6)$$

$$\ln y_i = 2.71 - 0.812 \ln \frac{w_i}{z_i} - 0.654 \ln z_i \quad (7)$$

where  $z_i$  is the maximum load of the truck assigned to  $U_i$ . The total CO<sub>2</sub> emissions that result from transporting cargo along routes  $\mathbf{r}_1, \mathbf{r}_2, \dots, \mathbf{r}_M$  is calculated as follows:

$$f(\mathbf{r}_1, \dots, \mathbf{r}_M) = \sum_{i=1}^M w_i \times d_i \times y_i \times \alpha \times 10^{-3} \quad (8)$$

VRCAP-MCMCE can be considered as an optimization problem that find the vectors  $\mathbf{r}_1, \mathbf{r}_2, \dots, \mathbf{r}_M$ , that minimize the objective function in equation (8) while minimizing the outsourcing fee.

### 3. METHOD FOR SOLVING VRCAP-MCMCE

The appropriate cargo allocation for the cargo carrier places more emphasis on outsourcing fee than CO<sub>2</sub> emissions. First, a tentative cargo allocation with low outsourcing fee is defined using a simple and easy procedure. Then, the cargo allocation is adjusted so that CO<sub>2</sub> emissions are reduced while outsourcing fee is kept at or below the original tentative allocation. In other words, the cargo allocation is adjusted so that the total transportation costs for the subcontractors are reduced. Repeated adjustments lead to reductions in both cost and CO<sub>2</sub> emissions.

The entire procedure is as follows:

1. Calculate a route that visits all delivery points using Dijkstra's Algorithm. The route's starting point is set to the farthest delivery point from the depot. The dpIDs are renumbered according to the servicing order of this initial route.
2. Each cargo is allocated to a truck in the order of the newly assigned dpID. The largest available truck that has sufficient space available for the cargo is selected. When there are two or more trucks whose maximum load are same, the truck with the smallest serial number is selected.
3. Calculate a delivery route for each truck and the corresponding CO<sub>2</sub> emissions.
4. Select a delivery point randomly. If cargo for the selected delivery point cannot be moved to another truck, skip to step 6.
5. If any of the following three conditions is satisfied by moving the cargo, move the cargo to another truck and skip to step 8.
  - ♦The truck becomes empty.
  - ♦The truck can be downsized to a smaller truck.
  - ♦The total CO<sub>2</sub> emissions decrease.
6. Randomly select another delivery point that is assigned to the different truck from the delivery point selected in step 4. If swapping the cargos for these two delivery points is feasible and decreases the total CO<sub>2</sub> emissions, swap the cargos and then skip to step 8.
7. If the step 6 has been repeated less than *Adjust* times, go back to step 6.
8. If steps 4–7 have been repeated less than *Adjust2* times, go back to step 4.

Each truck is given a serial number based on the truck's maximum load. *Adjust* and *Adjust2* are parameters that define the degree of thoroughness for the searching operation. In step 1, the dpIDs are renumbered to prevent the solution from being affected by the dpID numbering. If cargo allocation is performed based on only cargo weights, the transport distance will become large meaninglessly. Cargos for delivery points that are located near one another should be allocated to the same truck. By allocating cargos in the order of dpID in Step 2, cargos for neighboring delivery points are likely to be allocated to the same truck. In addition, by giving priority to a larger truck in Step 2, the number of the trucks to be used, i.e., the outsourcing fee decreases.

In step 3, 5 and 6, the delivery route for each truck is searched to calculate CO<sub>2</sub> emissions. The total weight of all cargos assigned to each truck must be equal to or less than the maximum weight of the truck. It is not necessary to consider using a truck more than once. Delivery routes are searched using the method proposed in previous work (Otani, 2011). The approach is based on symbiotic evolution and results in a fast, efficient search that is prevented from converging to suboptimal solutions.

The first two conditions in step 5 are satisfied if a less expensive cargo allocation has been found. Moving cargos without considering CO<sub>2</sub> emissions puts more emphasis on outsourcing fee. If the last condition in step 5 is satisfied, the total cost for subcontractors decreases without increasing the outsourcing fee for the cargo carrier.

#### 4. EXPERIMENTS

To confirm the effectiveness of our proposed method, experiments were conducted using both actual data and synthetic data. Parameters are listed in Table 1. As the search of the delivery route is repeated in each cycle, population size and maximum generation were set lower than in previous work not to increase the calculation time too much.

Parameter Name	Value
Whole and partial solution population size	300
Maximum generation ( <i>G</i> )	5000
Number of trial times of swapping cargos ( <i>Adjust</i> )	20
Number of trial times of the routine for moving and swapping cargos ( <i>Adjust2</i> )	300

Table 1: Parameters

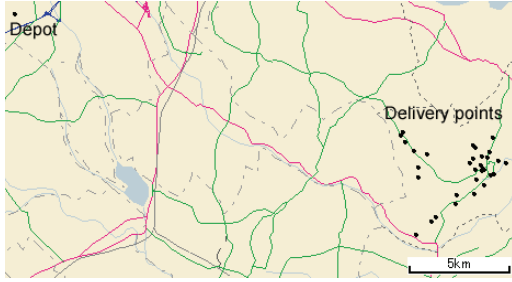


Figure 1: Locations of the depot and delivery points

Scenario	Cargo weight
<i>flat</i>	for all $i$ $w_i = 186$ kg
<i>heavy1</i>	$w_6 = w_{25} = 750$ kg, others = 150 kg
<i>heavy2</i>	$w_1 = w_{13} = 750$ kg, others = 150 kg
<i>heavy3</i>	$w_9 = w_{18} = 750$ kg, others = 150 kg

Table 2: Cargo weight scenarios

#### 4.1 Evaluation with actual data

We collected actual data from a cargo carrier in Inashiki city, Japan. The data contained all transport distances between all combinations of the depot and their 32 customers. Locations of the depot and the delivery points are shown in Figure 1. Four scenarios were defined for potential cargo weights, as listed in Table 2. In this section, the dpIDs shown correspond to the dpIDs after renumbering with Dijkstra's Algorithm. The total cargo weight is 6000 kg. Cargos in these data should be divided into units. The delivery of very heavy cargo to two delivery points is simulated using scenarios with the prefix "heavy." The subcontractors own two lightweight trucks, two 1 ton trucks and two 2 ton trucks. The maximum load of a lightweight truck is 350 kg.

The VRCAP-MCMCE is solved using the proposed method. Table 3 shows the total transport distance, total CO<sub>2</sub> emissions, and number of trucks required for the tentative cargo allocation obtained before adjustment and the final cargo allocation obtained after adjustment for all four cargo weight scenarios. There was no change in the number of trucks required for any of the scenarios, but the CO<sub>2</sub> emissions decreased after performing the adjustment procedure. Therefore, the cargo allocations with lower CO<sub>2</sub> emissions were obtained without increasing the outsourcing fee.

The delivery routes for *heavy-1* before and after adjustment are shown in Figures 2(a) and 2(b), respectively. The figures show enlarged maps of the delivery points. The dpIDs with a circle are the delivery points for heavier cargos. The dpIDs indicated with arrows correspond to the first visited point,  $r_i[1]$ . Although a route between two delivery points is denoted by a straight line, the trucks actually move along roads. The red, blue, and green lines correspond to the delivery routes for the 2 ton trucks, 1 ton trucks, and lightweight truck, respectively.

Scenario	Adjust	Transport distance [km]	CO <sub>2</sub> emission [kg-CO <sub>2</sub> ]	No. of trucks		
				2 t	1 t	light
<i>flat</i>	before	436.21	154.57	2	2	2
	after	397.09	144.45	2	2	2
<i>heavy1</i>	before	355.47	137.01	2	2	1
	after	340.34	132.99	2	2	1
<i>heavy2</i>	before	360.02	137.99	2	2	1
	after	344.24	133.59	2	2	1
<i>heavy3</i>	before	359.79	138.15	2	2	1
	after	343.14	133.75	2	2	1

Table 3: Effects of adjustment with the actual data

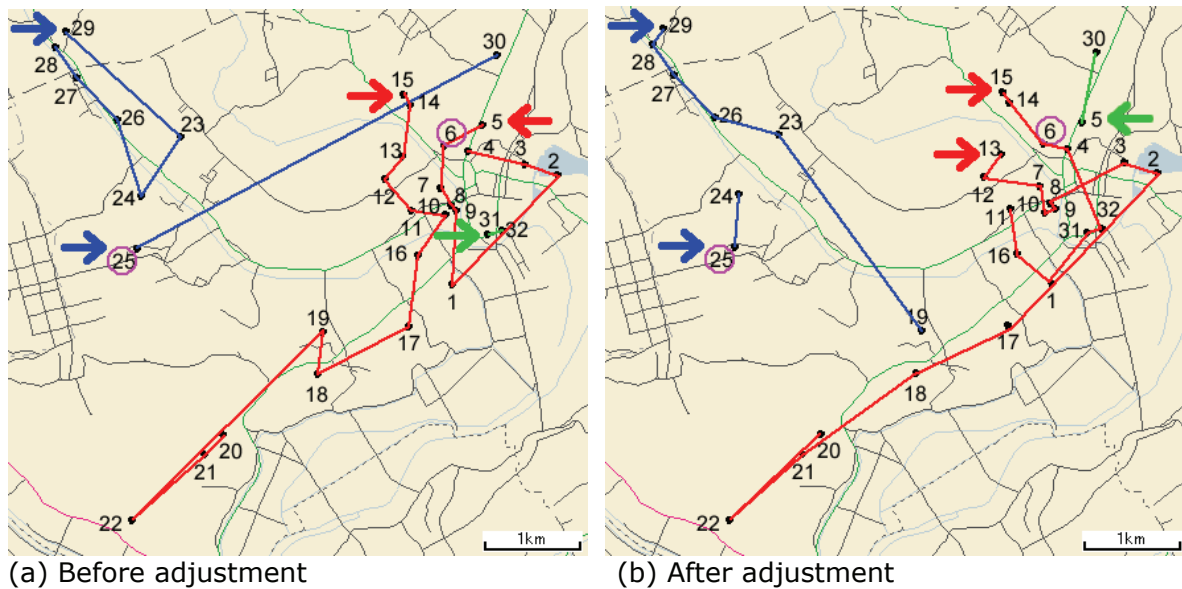


Figure 2: Route for *heavy1*

Delivery of heavier cargo is typically performed early in each delivery route to reduce CO<sub>2</sub> emissions. It is important to note that the delivery points that were assigned to the same unit as the delivery point with heavier cargo changed during the adjustment. Before adjustment, delivery point 6 was assigned to a unit that included delivery points located far from the depot. After adjustment, however, delivery point 6 belongs to the same unit as delivery points 14 and 15, which are closer to the depot than delivery point 6. Lighter cargos are unloaded on the way to the delivery point 6 with this allocation. In addition, delivery point 25 was originally assigned to a unit with delivery point 30, creating a long path with few deliveries. After the cargo allocation adjustment, delivery point 25 is included in the same unit as delivery point 24, which is in the same neighborhood. These results show that delivery routes with lower CO<sub>2</sub> emissions were obtained using the proposed approach.

#### 4.2 Evaluation with synthetic data

To confirm the effectiveness when applied to a large number of delivery points, an experiment was also conducted with synthetic data. 100 delivery points are located on the grid in  $xy$ -plane within  $0 \leq x \leq 9$  and  $0 \leq y \leq 9$ . The depot is located on the point (5,30) that is far from delivery points. The transport distance between two delivery points is defined as the Manhattan distance. Each division of the  $x$ -axis and  $y$ -axis is 6



km and 3 km, respectively. The cargo weight for each delivery point is defined randomly, ranging from 100 kg to 1000 kg. The delivery point locations and cargo weights are shown in Figure 3. Red points show the delivery points and the number to the right of each red point indicates the cargo weight associated with that delivery point. Subcontractors own five 2 ton trucks, five 4 ton trucks, and five 10 ton trucks.

The VRCAP-MCMCE based on synthetic data is solved with the proposed method. Table 4 shows the total transport distance, total CO<sub>2</sub> emissions, and number of trucks used for the tentative cargo allocation obtained before adjustment and the final cargo allocation obtained after adjustment. Both the cost and CO<sub>2</sub> emissions were decreased through the adjustment algorithm.

The delivery routes before and after adjustment are shown in Figures 4(a) and 4(b), respectively. Delivery points in each neighborhood belong to the same unit before adjustment. However, widely separated delivery points are included in the same unit after adjustment. This phenomena is a result of the fact that smaller trucks are being employed to decrease the total CO<sub>2</sub> emissions.

### 5. CONCLUSION

In this paper, we defined VRCAP-MCMCE to minimize the transportation costs for both a cargo carrier and their subcontractors, and proposed a method to solve this problem. Experimental results show that allocating cargo to trucks with the proposed method does not increase cost for the cargo carrier, but does decrease costs for the subcontractors. And this method also makes possible to reduce the CO<sub>2</sub> emissions on delivery activities. In the future, VRCAP-MCMCE should be extended to address additional practicalities. For example, the maximum load of a truck may be restricted for some delivery points or the delivery time may be constrained. It is important to take such situations into consideration and address them.

### ACKNOWLEDGMENTS

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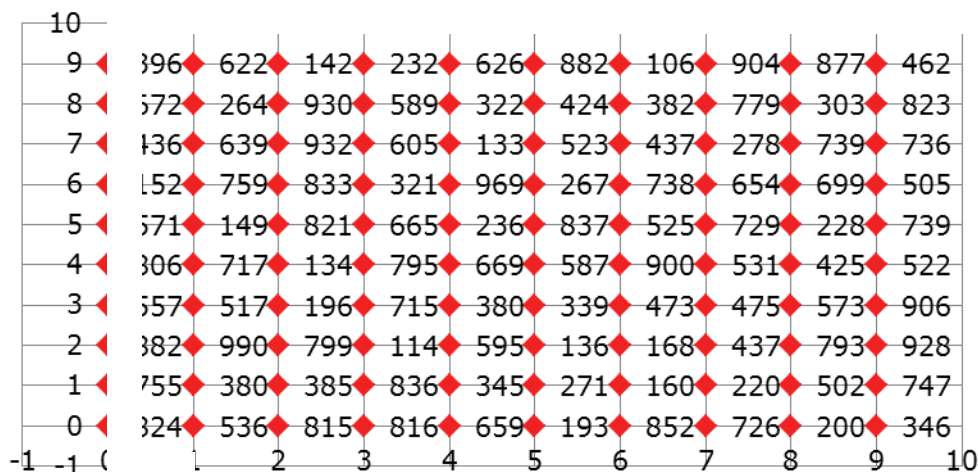
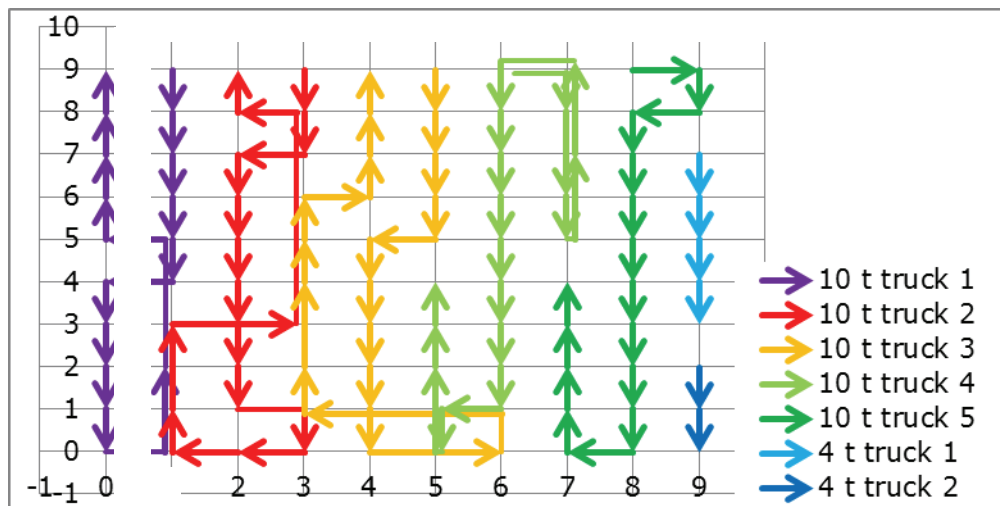


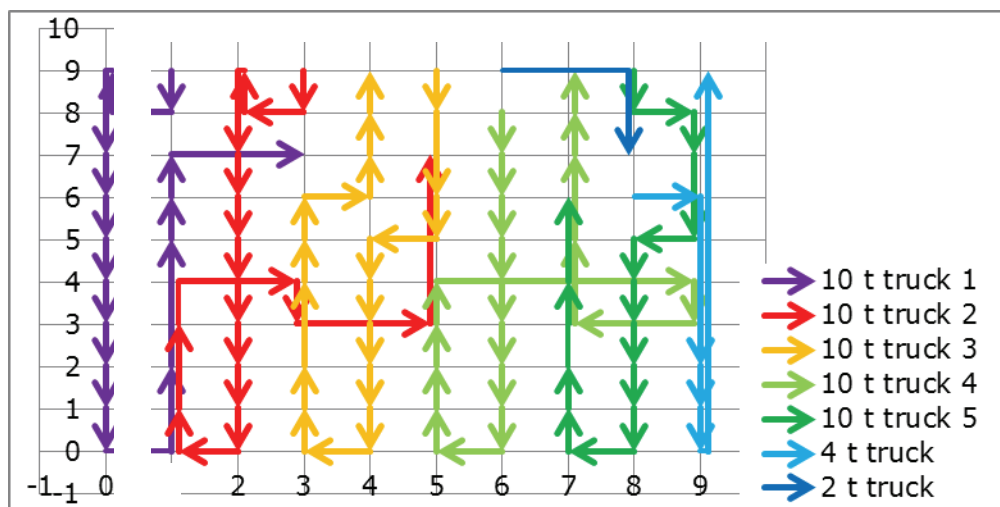
Figure3: Locations of the delivery points and cargo weights [kg] in the synthetic data

Adjust	Transport distance [km]	CO <sub>2</sub> emission [kg-CO <sub>2</sub> ]	No. of trucks		
			10 t	4 t	2 t
before	1626	1233.06	5	2	0
after	1566	1178.94	5	1	1

Table 4: Effects of adjustment with the synthetic data



(a) Before adjustment



(b) After adjustment

Figure 4: Route for the synthetic data

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## A STUDY OF SAFETY ATTRIBUTES OF PETROCHEMICAL TANKER TERMINAL OPERATION

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**Purpose of this paper:** Human error is the major contributor to fatal accidents occurred in petrochemical tanker terminals in a port. To search for safety attributes influencing the ship-shore cargo handling operation in tanker terminal in Taiwan and to find critical safety factors, an empirical survey to executives of tanker terminal operators is carried out to help tanker terminal operator effectively reduce the odds of accidents occurred in their terminal.

**Design/methodology/approach:** Three major petrochemical terminal operators in the Kaohsiung Port are chosen, 220 copies of questionnaires are dispatched, and 188 copies of valid response are received. This survey result is analysed by the Exploratory Factor Analysis technique and Importance-Performance Analysis (IPA) model. Thirty seven safety service attributes are categorized into the following ten safety dimensions by the principal component analysis technique: deck operational management, vessel-to-shore interface management, accidents prevention, safety training, contingency planning, equipment application management, environmental protection, powered vessel, fire-fighting training, and professional expertise dimensions. Finally, based on Importance-Performance Analysis and several post-survey interviews with tanker shipping academicians, two strategies to improve the tanker terminal safety management practice are provided.

**Findings:** Two of the 37 attributes influencing safe cargo handling in petrochemical tanker terminals were found to have above average degree of importance with below average degree of performance, namely, the regulation on the shipboard oil water discharge and regular fire drills by ocean tanker terminal operators. These findings imply staffs training by terminal operators and port safety regulation by port state are the most urgent issues to be improved if tanker terminal operators want to effectively reduce the odds of accidents occurred.

### **What is original/of value in paper?**

The consequence of an accident occurred in tanker terminal operation might be catastrophic, but few researches have looked into the factors influencing tanker terminal operation. The most used safety operation guidelines were published by the Society of International Gas Tanker and Terminal Operators (SIGTTO) in 2006. Our research findings can contribute an effective strategy to improve the safety performance of tanker terminal operators.

### **Research limitations/implications (if applicable)**

Only executives of two major the tanker terminal operators are surveyed. Future researches can extend to survey tanker terminal users' perception on the importance and performance of the 37 safety attributes. These major users should include but not limit to the ocean tanker carriers and the tank truck operators.

### **Practical implications (if applicable)**

Current regulations demand tanker terminal operators to carry out fire drill at least once a year, authors suggest government agency revise the regulations to increase fire drills frequency to ensure the tanker terminal employees are familiar with the fire fighting procedure and can effectively extinguish a fire when it occurs. Shipboard oil water discharge into the port area should be included in the routine PSC inspection item before a chemical tanker can loading and discharging their petrochemical cargoes.

**Keyword:** Petrochemical, ISGOTT (International Safety Guide Oil Tanker and Terminal), Principal Components Analysis, Importance-Performance Analysis(IPA)

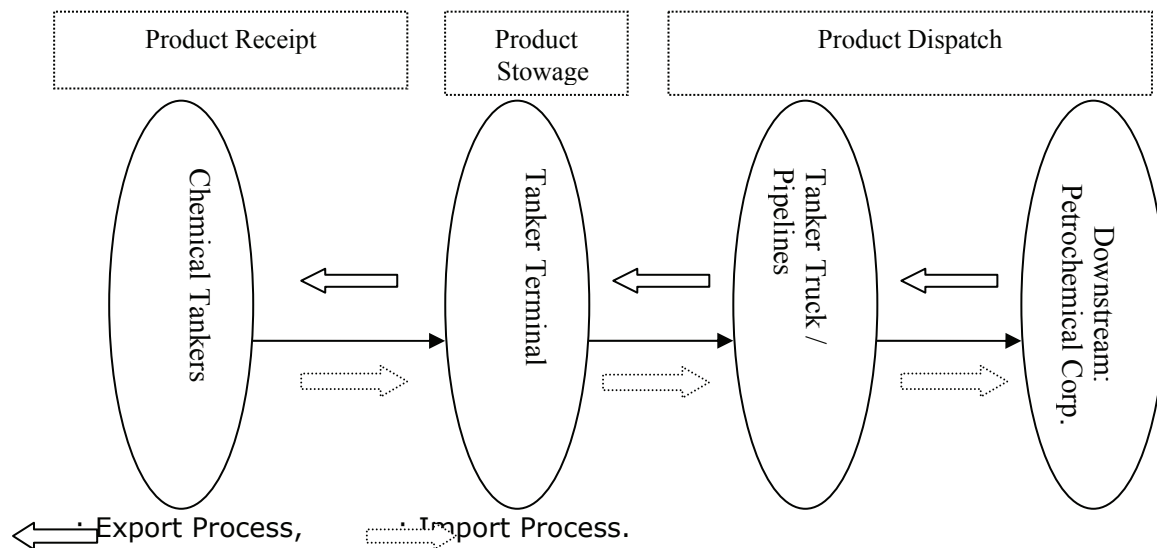
## Introduction

Petrochemical industry is a capital, technological, and labour intensive industry, and its final products are broadly used in our daily life. According to the Great Soviet Encyclopedia, petrochemical industry is 'a branch of heavy industry encompassing the production for synthetic materials and items, mainly from products derived from the refining of petroleum and natural fuel gases' (Farlex, 2013). As the introduction of new petroleum-refining methods—cracking and pyrolysis in the early twenty century, the petroleum becomes an important source of chemical raw materials. Taiwan has its first cracking naphtha cracking plant built in Kaohsiung in 1968, and Taiwan Formosa Plastic Corp. invested US\$17.7 billion in building its 6<sup>th</sup> naphtha cracking project which includes 54 plants in the offshore zone in the central Taiwan in 1991 (FPCC, 2013). The project's annual production value in 2011 has reached US\$50.8 billion, which is 9.2% of Taiwan's GDP and 30% of Taiwan's manufacturing products output in terms of value for the same year. There are 42 member companies in the Petrochemical Industry Association of Taiwan (PIAT, 2013).

Because Taiwan has most of its crude oil imported from the Middle East, when the crude oil and product oil tankers discharge these liquid cargoes in Kaohsiung oil tanker terminals, safety management becomes terminal operators' first priority before the operating efficiency.

## Refined and Liquid Petrochemicals handling process in tanker terminals

There are 507 million deadweight tons of crude and product oil carriers with an average age of 16.37 years in service in 2012 worldwide (UNCTAD, 2012). In addition, there are 44 million deadweight tons of liquefied gas carriers. Both carriers required sophisticated management & facilities in tanker terminals to handle their cargoes safely. The process of tanker terminals operation can be divided into three modules, (1)Product receipt module, (2)Product storage module, and (3) Product dispatch module (see figure 1).



Source: SIGTTO (Society of International Gas Tanker & Terminal Operators) & Ou (2009)  
Figure 1 Tanker terminal operation

## Safety Management

As the consequence of a minor human error occurred in a tanker operation can result in a catastrophe, it cannot be overemphasized the importance of safety management in the terminal. Arslan & Deha Er (2008) studied the safe carriage of bulk liquid chemicals in ocean tankers by SWOT analysis, they found there are three groups of weakness factors: human-related factors (fatigue, poor judgment, extreme boredom, improper supervisory, inadequate skill), operational factors (inadequate rules, policies, standards; inadequate work planning, inadequate vertical and horizontal communication; inadequate identification of worksite; inadequate performance measurement and assessment; inadequate risk assessment), and job-related factors (inadequate leadership, inadequate safety culture, inadequate team culture, existence of chemical hazards). Arslan (2009) employed the analytic hierarchy process (AHP) to prioritize the actions to prevent marine casualties derived from chemical tankers accidents. Seven major actions are identified in the Arslan's research, (1) Berthing alert, (2) Alert on an individual's action, (3) Alert on deck equipments (4) Alert on issues occurred outside the ship, (5) Possible emergency alerts, (6) Alert on cargo handling process, and (7) Bunkering system. Hee et al. (1999) studied the marine operation and found more than 80% of accidents reported in a marine system are resulted from human and organizational errors. A panel of risk and insurance managers in the marine industry were taking questions at the annual RIMS (Risk and Insurance Manager Society) also indicated 99% of all accidents were caused by humans' or organizations' errors and omissions (RIMS, 2005). They proposed a safety management assessment system (SMAS) composed of seven modules: structure, procedures, organization, operating team, interfaces, equipment/hardware, and environment. Numerical data analysis can reduce the likelihood of an accident occurred. Similar factors possible influencing the safe operation of a tanker marine terminal are indicated by the International Chamber of Shipping (2006).

## Questionnaire Design, Research Process, and Findings

Importance-performance analysis technique and principal component analysis techniques are employed to investigate the critical attributes influencing the tanker terminals operational safety perceived by employees of three major tanker terminal operators headquartered in Kaohsiung. There were 110 copies of questionnaires with 37 safety-related questions (see table 1) distributed to employees in the three tanker terminals, 102 copies of them are return and 94 copies of the received responses are valid for the following analysis. Interviewing one senior tanker terminal managers and one retired tanker captain, these 37 questions are confirmed to be crucial to ensure the tanker cargo handling operation safety during her berthing in a terminal. Using the value of average importance and average satisfaction to draw an importance-performance analysis matrix as shown in the figure 2, attributes with higher degree of importance and lower degree of performance are identified as crucial attributes in the 'concentrate here' quadrant.

Table 1 Items Influence the Operational Safety of a Tanker Terminal

(Degree of Importance & Satisfaction)

Items/Questions		Importance		Satisfaction	
		Average	Std. Dev.	Average	Std. Dev.
V1	Good communication and using pilots during the berthing process	3.57	1.011	3.55	1.001
V2	Fire fighting hoses and equipments are ready to be used on the ships	3.64	0.937	3.60	0.987
V3	Unused manifolds and pipelines on deck are properly sealed.	3.70	0.890	3.73	0.941
V4	Ships can use their own power to move to a safe berth in case of an emergency occurred	4.01	0.539	3.78	0.778
V5	Security guards are on alert during cargoes handling process	3.34	1.043	3.49	0.992

Items/Questions		Importance		Satisfaction	
		Average	Std. Dev.	Average	Std. Dev.
V6	Mooring wires on their auto-tension position to overcome the draft changes between ebbs and flood and cargo loading and discharging	3.91	0.542	3.64	0.788
V7	Cargo holds' high level alarms functioned properly during liquid cargo loading	3.57	1.021	3.64	1.014
V8	Insert Gas System (IGS) functions properly	4.07	0.572	4.18	0.528
V9	Proper loading and discharging plan	4.05	0.575	4.03	0.695
V10	To stop the radio communication and radar detection system once the ship is on her berth	3.12	1.004	3.33	0.966
V11	To stop all food provision supply and ship maintenance work during cargo handling process	2.61	0.845	2.33	0.724
V12	Personal protective equipments	3.86	0.770	3.98	0.688
V13	Petrochemicals protection & training handouts	4.14	0.579	4.02	0.789
V14	Scheduled contingency and fire drills in the tanker terminal	3.96	0.527	3.47	0.980
V15	Regular safety training provided to employees in tanker terminals	2.35	0.772	2.27	0.706
V16	Good shipboard communication with tanker terminal before berthing	3.64	0.926	3.57	0.945
V17	Providing a good ship-to-terminal communication channel after berthing	3.33	0.977	3.45	1.012
V18	Agreement on proper loading/ offloading pressure and proper cargo handling speed	3.57	0.898	3.55	0.957
V19	Fire fighting equipments on board and on the terminal are standing by. They are ready to be used once an emergency occurred	3.55	0.911	3.80	0.697
V20	Tanker's cargo discharging plan matched with the terminal's cargo receiving plan	3.61	0.964	3.90	0.777
V21	Good monitoring system on board and on shore during cargo handling process	3.36	0.949	3.33	0.966
V22	Common language or gestures to improve communication between tanker and terminal	3.56	0.979	3.55	0.969
V23	Spare equipments available once a contingent oil and gas leakage occurred	4.04	0.527	3.79	0.866
V24	All loading and discharging procedure are always double checked before starting the procedure	3.50	1.034	3.69	0.962
V25	Proper function of emergency pressure relief vale once abnormal pressure observed in ship- shore pipelines	3.63	0.904	3.53	0.947
V26	Proper high level alarm in the ships' and terminal's cargo tanks	3.57	0.933	3.46	0.969
V27	Proper functioning of remote control vale between ship and shore	2.47	0.851	2.37	0.816
V28	Available of emergency telephone between ship and shore	3.33	0.897	3.47	0.876
V29	Proper ship-shore emergency piping switch system design	3.84	0.723	3.79	0.828
V30	Proper functioning of ship-shore emergency interrupting vale	3.51	0.970	3.69	0.916
V31	Proper one way valve in the terminal's cargo discharging pipeline	3.90	0.657	3.82	0.775
V32	Using inert gas to protect tanker cargo holds	3.34	1.032	3.59	0.966
V33	Proper protective device available when cargo discharging equipments are out of the position because of a strong wind	3.24	1.084	3.18	1.126
V34	Proper alarm devices when gas cargo & oil cargo leak	2.22	0.721	2.35	0.786

Items/Questions		Importance		Satisfaction	
		Average	Std. Dev.	Average	Std. Dev.
V35	Proper regulations on the oil sewage discharge	3.60	0.896	3.52	0.947
V36	Regular drills on the use of fire fighting equipments and oil pollution prevention systems on the shore	3.95	0.536	3.91	0.599
V37	Sufficient tank capacity to receive petrochemicals discharged from tankers	2.47	0.851	2.50	0.852

Note: Scale on the degree of importance : 1=Very unimportant, 2= unimportant , 3=neither important and unimportant, 4= important, 5=very unimportant

Scale on the degree of satisfaction: 1=Very unsatisfied , 2= unsatisfied , 3=neither unsatisfied nor satisfied, 4= satisfied, 5=very satisfied.

### Research Findings

Research results are exhibited in the figure 2. Only two items (v14 & v35) are perceived to be the determinants located in the concentrate here quadrants. However, respondents' degree of satisfaction on these two items is simply slightly less than the average degree of satisfaction on these 37 safety items. This implies the current safety operation practice of the three tanker terminal operators is well managed.

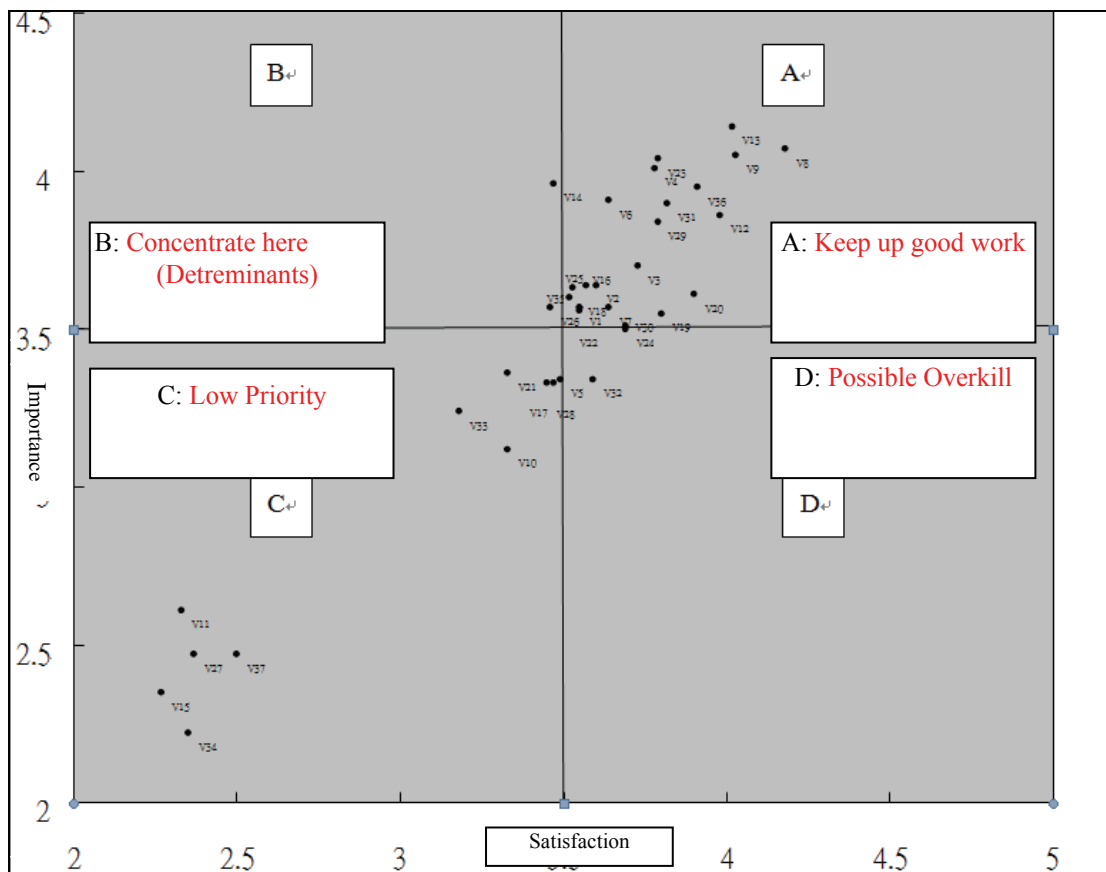


Figure 2 Tanker Terminal Operators' Safety Practice and the Importance- Satisfaction Matrix

Principal component analysis (PCA) technique is employed to convert these 94 respondents' perceptions on possibly correlated variables into several groups of values of linearly uncorrelated variables called principal components. A scree plot is exhibited as figure 3 to be used as a useful visual aid for determining an appropriate number of principal components. Using Eigenvalue = 1 as the threshold, there are ten groups of items should be remained after the PCA process. KMO values are calculated to interpret and measure the adequacy of these items to be grouped by the PCA technique. The KMO value is found to be 0.804 which implies it is meritorious to apply the PCA technique in our research.

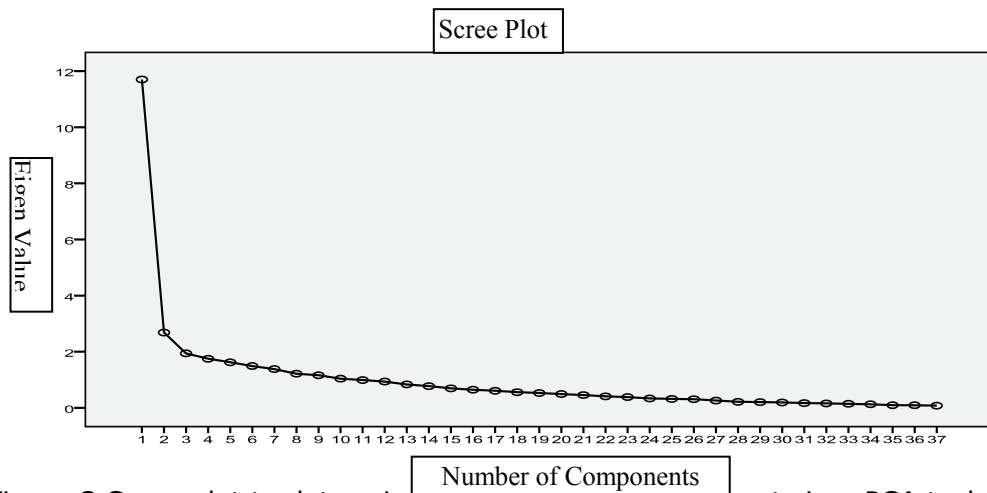


Figure 3 Scree plot to determine the number of components in a PCA technique

Varimax rotation is employed to change the coordinates used in principal component analysis, thus the sum of the variances of the squared loadings (squared correlations between items and factors) are maximized.

Table 2 Principal component analysis on the 37 safety items (variables) in tanker terminals

Factor	Questions	Factor Loading	Total amount of variance explained (%)	Naming factors
F1	3.Unused manifolds and pipelines on deck are properly sealed.	0.564	13.134	Deck operation safety
	8. Insert Gas System (IGS) functions properly	0.675		
	12. Personal protective equipments	0.636		
	16. Good shipboard communication with tanker terminal before berthing	0.721		
	18. Agreement on proper loading/ offloading pressure and proper cargo handling speed	0.709		
	20. Tanker's cargo discharging plan matched with the terminal's cargo receiving plan	0.620		
	24. All loading and discharging procedure are always double checked before starting the procedure	0.546		
	25. Proper function of emergency pressure relief vale once abnormal pressure observed in ship-shore pipelines	0.541		
F2	2. Fire fighting hoses and equipments are ready to be used on the ships	0.708	25.767	Ship-shore operation safety
	1. Good communication and using pilots during the berthing process	0.633		
	26. Proper high level alarm in the ships' and terminal's cargo tanks	0.698		
	32. Using inert gas to protect tanker cargo holds	0.660		
	35. Proper regulations on the oil sewage discharge	0.604		
	7. Cargo holds' high level alarms functioned properly during liquid cargo loading	0.598		
	37. Sufficient tank capacity to receive petrochemicals discharged from tankers	0.738		
F3	21. Good monitoring system on board and on shore during cargo handling process	0.776	36.715	Accidents prevention
	17. Providing a good ship-to-terminal communication channel after berthing	0.630		
	28. Available of emergency telephone between	0.629		



Factor	Questions	Factor Loading	Total amount of variance explained (%)	Naming factors
	ship and shore			
	30. Proper functioning of ship-shore emergency interrupting valve	0.605		
	33. Proper protective device available when cargo discharging equipments are out of the position because of a strong wind	0.515		
	11. To stop all food provision supply and ship maintenance work during cargo handling process	0.502		
F4	15. Regular safety training provided to employees in tanker terminals	0.709	42.808	Safety training
	19. Tanker's cargo discharging plan matched with the terminal's cargo receiving plan	0.626		
F5	23. Spare equipments available once a contingent oil and gas leakage occurred	0.809	48.711	Emergency response
	29. Proper ship-shore emergency piping switch system design	0.655		
F6	34. Proper alarm devices when gas cargo & oil cargo leak	0.828	53.924	Equipment application
F7	36. Regular drills on the use of fire fighting equipments and oil pollution prevention systems on the shore	0.771	58.767	Environment protection
	27. Proper functioning of remote control valve between ship and shore	0.642		
F8	4. Ships can use their own power to move to a safe berth in case of an emergency occurred	0.834	62.736	Ship maneuverability
F9	14. Scheduled contingency and fire drills in the tanker terminal	0.928	66.680	Fire drills
F10	13. Petrochemicals protection & training handouts	0.774	70.240	Professional know-how
	9. Proper loading and discharging plan	0.569		

## Conclusions and Discussions

Ten groups of variables accounted for 70.24% of variance to explain the safety management of tanker terminal operations. These ten groups of variables are named as deck operation safety, ship-shore operation safety, accidents prevention, safety training, emergency response, equipment application, environment protection, ship maneuverability, fire drills, and professional know-how. The top four factors account for 42.808% of variance to the tanker terminal operational safety.

Tanker terminal operators in Kaohsiung can move part of their resources in variable 32 ('Using inert gas to protect tanker cargo holds') in the possible overkill quadrant to improve their performance on the safety variable 14 ('Scheduled contingency and fire drills in the tanker terminal') and variable 35 ('Proper regulations on the oil sewage discharge') in the concentrate quadrant.

Possible avenues for future research can focus on comparing tanker terminal operators' performance differences between the petrochemicals exporting nations and importing nations. An extended study on tanker shipowners' safety management when their ships are alongside the tanker terminal can also be used to compare the findings in our research.

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# COMPETITIVENESS OF GLOBAL PORT CITIES: A PATH DEPENDENT ANALYSIS OF THE PORT OF ROTTERDAM

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## 1. INTRODUCTION

The competitive environment affecting ports operation is in a constant state of flux. A comparison of the leading ports across the globe during the last few decades reveals that ports have been changing positions in global rankings. The shift in the ranking reflects the intensive dynamic competition between ports to attract cargo. Statistics on total cargo volume handled, measured in TEUs, show that during the last few decades a number of major port cities, such as Hamburg and Antwerp, which were on the top 10 in port ranking between late 1970's and early 2000's, had dropped to lower positions in late 2000's (Rodrigue, 2010). Others, such as Rotterdam and Singapore, were, however, able to maintain their status on the top 10 list.

Research on port competitiveness has been a dominant theme among maritime and port studies for more than two decades. In 1990's a structure suggested by Rugman and Verbeke (1993), based on Porter's (1998) Diamond model, suggested that there were six factors that led to innovation and a port's competitive position: 1) factor conditions (e.g., production, labour and infrastructure) , 2) demand conditions, 3) related and supporting industries, 4) firm structure and rivalry, 5) chance and 6) government intervention. In early 2000s and during the process of introducing value added chains, prime factors supporting port competitiveness were identified as hinterland accessibility, productivity, quality, cargo generating effect, reliability and reputation (Meersman et al., 2002). A more recent study on port competitiveness (Carbone et al. (2007), however, suggested that factors influencing port competition have evolved into the following:

- Relationships with other actors in the supply chain
- Availability of port-infrastructure
- Proximity to major sourcing and final markets
- Road/Rail network configuration
- Transit time
- Number of direct connections to overseas destinations
- Extent of feeder service
- Good labour climate
- Inland waterways connections

The changing factors affecting port competitiveness imply that ports that managed to retain their competitive strengths over the last two decades are likely those that have moved with the tune of the time and are not dependent on their natural endowment, like a deep sea harbour, as have been the case in the past (Veltz, 2001). Rather obviously, the massive built-up in port capacity and port-related resources (Haralambides, 2002), as well as major improvement in transport systems that led to the extension of port hinterlands (Ducruet, 2009) during the last two decades are deliberate, and strategic, actions taken by far-visioned port authorities.

Port development is a historical process, where the important sequence of changes occurs through growth and is hard to be reversed at a later stage. In this context, port development can be argued as a path-dependent process, where future events would not be independent of past events and the sequence of events, as well as the manner in which they occur, make a difference on the outcome (Notteboom, 2009). As argued by Notteboom (2009), path dependency explains the reason that port systems across the world have not developed in the same pattern or followed a similar sequence. Notteboom (2009) also noted that ports are generally subject to open economic structures which are founded on market-based principals and for the same reason port developments vary to a great extent across the globe.

Furthermore, port development requires a number of key resources. These critical assets, commonly categorized into Infrastructures, Superstructures, Human Capital and

Information and Communication Technologies System (Meersman et al., 2002), are necessities for the conduct of value-added logistics activities (De Martino and Morvillo, 2008), which have become an integral part of port operations. Once these infrastructural investments are in place, the resources allocated, as well as general policies designed to support their development, may not be readily overturned.

**2. RESEARCH AIM, FOCUS AND METHODOLOGY**

In line with the above argument, this study contends that understanding the dynamic complexity determining port competitiveness is not limited to identifying factors contributing to port success. Such an understanding requires an in-depth evaluation of the growth and developmental path that a port has traversed, either by default or by design, or both. This research examines how Rotterdam builds its competitive capabilities to sustain its competitive position as one of the top container ports in the world.

The Port of Rotterdam has been selected as the case study due to its sustained status on the world’s top 10 container traffic port list since the early 1990s and also its statute as one of the “foci” of international trade. In analysing the growth and developmental path of the Port of Rotterdam, this paper focuses on three main themes: 1) growth of container traffic (based on TEUs) during the last two decades, 2) major development events of historical significance, and 3) competitive strategies introduced in the last two decades. In combination, the three thematic analyses are attempts made to answer two research questions:

- What progressive and proactive actions have been taken by the Port of Rotterdam to convert opportunities to competitive advantages?
- How did the Port of Rotterdam manage to make its locational disadvantages irrelevant?

The analysis was based exclusively on secondary data sourced from published information on, or related to, the growth and development of Rotterdam since the 1990’s, in particular literature and reports made available to public by the Port of Rotterdam Authority during the last 20 years.

**3. ANALYSIS**

**3.1 Container Traffic**

Known as the largest port in Europe, Rotterdam has been one of the busiest ports in the world since 1960’s. It has held its position as one of the top 10 busiest container ports in the world since 1989, though its ranking has been on the decline in general (Figure 1).

**3.2 Historical Development**

Beginning of Rotterdam can be traced back as far as mid 1300’s, when its primary economic activities were based largely on fisheries and cargo handling. Good location and political circumstances favoured Rotterdam to flourish through trade with other European countries and even America. While the Port of Rotterdam experienced significant growth between 1850 and 1940, major development only occurred only after World War II, anchored by a reconstruction plan designed to develop a bigger and deeper port in Rotterdam to act as a gateway to Europe. An overview of Port of Rotterdam is shown in Figure 2.

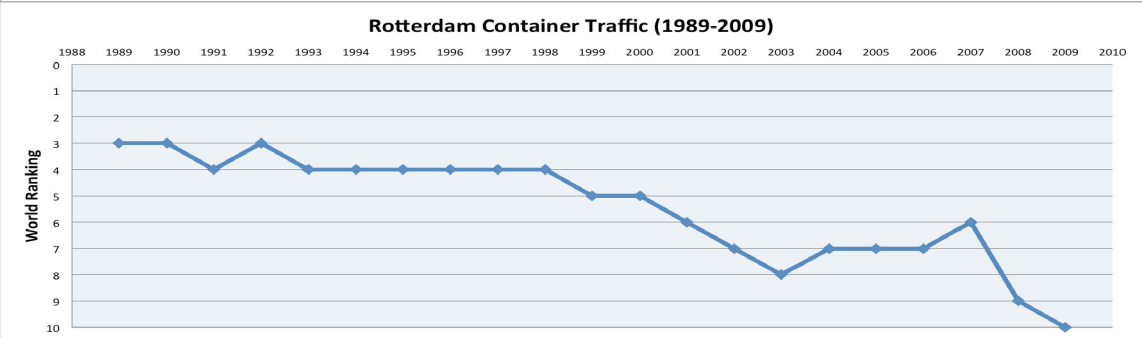


Figure 1 – Port of Rotterdam Ranking  
Source: Adapted from (Rodrigue, 2010)

▪ Worldwide and European ranking:	worldwide the 4 <sup>th</sup> port and the number one in Europe
▪ Total direct and indirect seaport-related value added and employment:	± 15,5 billion euro respectively ± 6,7 billion euro; ± 90.000 employees resp. ± 55.000 employees
▪ Role of the Port of Rotterdam Authority:	responsible for infrastructure, long-term planning and development, safety
▪ Total surface area and quay length:	10.570 ha. (excl. the ± 1.000 ha. of Maasvlakte 2) resp. ± 90 km
▪ Number of seaport-related business establishments:	± 1.315
▪ Tank storage capacity and pipeline length:	± 30 million m <sup>3</sup> resp. ± 1.500 km of pipelines
▪ Number of terminals:	50 (for containers, break bulk cargo, dry bulk cargo)
▪ Number of petroleum and chemical companies:	± 130 (incl. the largest refinery of Europe)
▪ Number of logistic companies in the logistic sector:	± 1220 (incl. transport and transshipment/storage/transfer services)
▪ Number of wholesale companies resp. (commercial and non-commercial) service companies:	± 650 resp. ± 270

Figure 2 – Overview of the Port of Rotterdam  
Source: (Port of Rotterdam, 2010)

The continuous renewal that took place in Rotterdam generated a unique position for its port, raising its importance to the economy of the Netherlands, as highlighted by a growth in employment rate of some 145,000 persons and an annual revenue of 22 billion Euro (Van Den Bosch et al., 2011). These developments and their associated spatial expansion (see Figure 3) were summarized into nine general trends by De Langen (2005) as follows:

- Uncertain growth prospects for freight transport;
- Commoditization of transport services;
- Production on manufacturing and logistics platforms;
- New quality levels in “industrial ecology”, sustainability and safety;
- Higher land efficiency in manufacturing (particularly chemical manufacturing), storage and terminal handling services;
- Mixed land use in the port complex;
- Increased need for an overall vision and organizing capacity;
- The need for an effective “regional innovation system”, an attractive climate for the “creative class”, and space for experiments; and
- Growth opportunities for port complexes: especially chemicals, recycling, manufacturing and logistics platforms

As the largest container port in Europe, Rotterdam’s traffic has been projected to reach 17 million TEUs in 2017, growing at an average utility rate of 78 per cent (Barnard, 2012). Developing the capability to handle such a large volume of traffic requires strategic long-term planning. With regards to container traffic in specific, Rotterdam has witnessed a series of innovations and development (Gijt et al., 2010) , which propelled this port to become the largest container hub port in Europe, ranking among the top 10 ports on the global scale. A summary of the infrastructure developments in container terminals at the Port of Rotterdam, which had led to major increase in port productivity, is presented in Table 1.

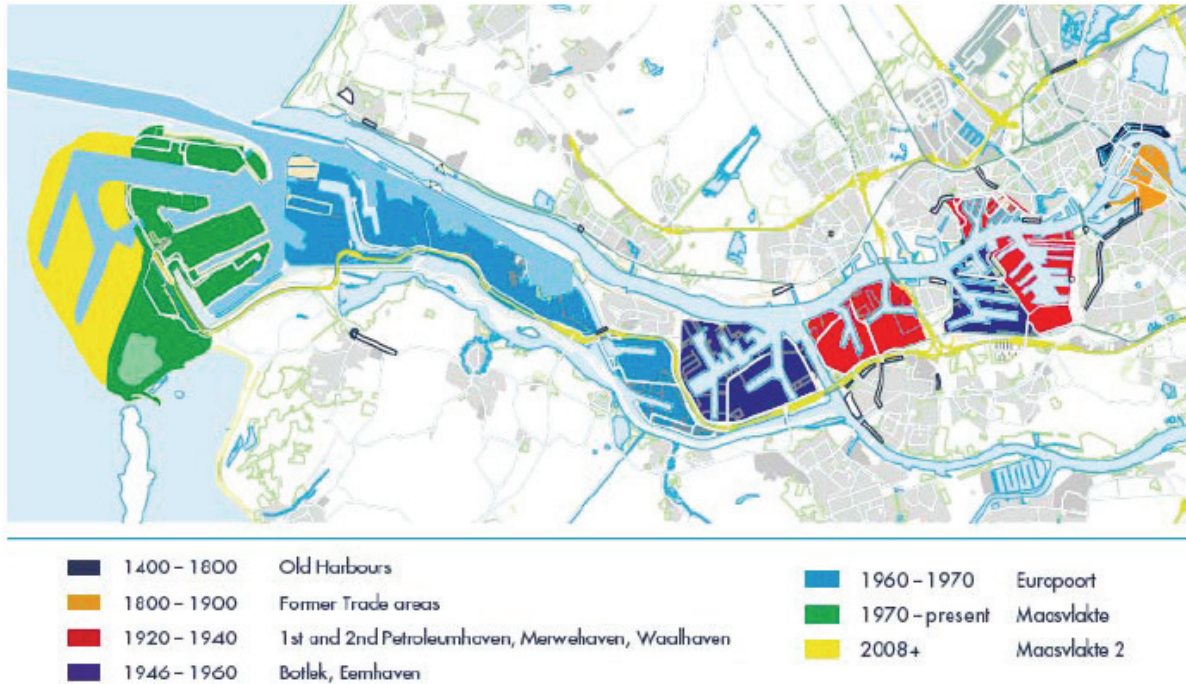


Figure 3 – Historical development of Port of Rotterdam  
Source: (Port of Rotterdam, 2013a)

Table 1- Characteristics of Container Terminal Development in Port of Rotterdam

Year	Berth length (m)	Crane capacity (kN)	Crane outreach (m)	Depth (m)	Area (ha)
1955	175	50	24	175	3
1965	250	400	35	230	5.7
1985	375	650	50	400	16
2009	500	1000	70	600	30

Source: Adapted from (Gijt et al., 2010, p. 12)

### 3.3. Competitiveness

Rotterdam's competitiveness has been explained by its comparative easy access to the European market via a range of transport modes: road, rail, inland shipping, coastal shipping and pipeline. Its superior location on the estuary of the rivers Rhine and Maas makes transport by inland vessel possible deep into Europe. Krekels and Wever (2008) attributed four factors that had been contributing to competitiveness of Rotterdam:

- Favourable geographical location within western Europe
- Location at the mouth of river Rhine
- Excellent connection with North Sea
- Coalition between port authority and city council

Although the factors contributing to port competitiveness have been changing during the last few decades, the favourable location of Port of Rotterdam remained as one of its comparative advantages. The other important traditional factor has been the coalition between the Port Authority and City Council, which gradually changed after 1970s when the city council started focusing more on environmental management, while the port authority was placing emphasis on economic issues. However, in the process of regenerating Rotterdam during 1990s, the "broken" coalition between the Port Authority and City Council was reconstructed when the latter took on a lead role in providing sustained commitments to the port communities (McCarthy, 1998).

Zauner (2008) did a SWOT analysis of Rotterdam seaport based on the internal and external environment of Rotterdam (see Figure 5), highlighting the foundation of strategic planning in this port-city. According to Zauner's (2008) analysis, scarcity of space has been the biggest challenge facing Rotterdam. To overcome this challenge and maintain its leading role in Europe, Rotterdam took proactive actions by reclaiming land in its harbour basins and creating higher ground by dumping sand and other materials to progressive expand its port (Gijt and de Horst, 1993). The large-scale projects that were

performed during the last few decades are Maasvlakte1, Distriparks (Eemhaven, Botlek, Maasvlakte) and Betuweroute. Maasvlakte2 is the most current extension of the Port of Rotterdam. As a major civil engineering project, Maasvlakte2 (Port of Rotterdam, 2013b) aims to strengthen Rotterdam as an international transport hub, expanding approximately 2,000 hectares of land adjacent to the existing port area. The project is designed to create space gradually over the next 20 years, for deep-sea transport and inland shipping to handle an additional 17 million TEUs (Port of Rotterdam, 2013b), as well as making better use of available space, and to improve the quality of the living environment by creating a new nature and recreational zones (Gijt et al., 2010).

An exceptional advantage of Maasvlakte 2 is the location in North Sea allowing the largest ships to moor in the port area 24 hours a day, a service that has not been offered by any other ports in Europe at present. Other advancements, such as direct connection to the double track freight railway from Rotterdam to Germany and other parts of Europe as well as a many other infrastructural advantages, are expected to make Maasvlakte 2 a long-term strategy to reinforce the status of Rotterdam as a transportation hub.

As for external threats, competition has been considered "the main" external force by the Port of Rotterdam authority (Zauner, 2008). The Port of Rotterdam has to compete with three different products in three different markets: 1- providing seamless transport (from ships to hinterlands), 2- attracting distribution and logistics activities to the port, and 3- offering favourable industrial location. For the first product, the severe competition is mainly with other European ports in proximity, such as Hamburg and Antwerp. However with regards to attracting distribution and logistics activities and/or the industrial

locations, Rotterdam is competing with other ports across the globe, such as Houston or Singapore. In terms of containerized traffic, there are four aspects known to affect competition between ports in the Le Havre-Hamburg range (Kreukels and Wever, 2008):

- Costs and productivity;
- Congestion on main roads;
- Limited capacity of the rail network; and
- Increasing number of restrictions, imposed by society on the transport sector mostly of an environmental nature, such as contamination, noise and pollution.

<p><b>Strengths (S)</b></p> <p>Industry structure Location Maritime accessibility Hinterland connections Size PoR authority</p>	<p><b>Weaknesses (W)</b></p> <p>Scarcity of space Road connection Intra-port competition Intra-port co-operation Reputation nationally</p>
<p><b>Opportunities (O)</b></p> <p>World trade Sustainable transport European Union (EU) Ship size Inter-port co-operation</p>	<p><b>Threats (T)</b></p> <p>World trade Energy change Labour market Stakeholder environment National government Industry concentration Competition</p>

Figure 5 - SWOT analysis of Rotterdam seaport  
Source: (Zauner, 2008, p. 137)

#### 4. DISCUSSION OF RESULTS

To better understand Rotterdam's competitiveness during the last two decades, a timeline of major events affecting the development of the Port of Rotterdam is presented, starting with the period of 1975-84 when the main Dutch urban centres were hit by the international and national recession. Although Rotterdam managed to maintain its position as the top port in Europe, transshipment statistics revealed an operational downturn. During this period, the port authorities and city administrators jointly took steps to fortify the competitive strength of the port. The outcome of this attempt was a strategic development plan, called "Port Plan 2010", which was officially approved in early 1990s (Kreukels, 2003). The main objectives of this plan were: 1) creating optimal accessibility, 2) strengthening the commercial and service sectors, and 3) reconstructing the existing sites and development of new premises (Kreukels and Wever, 2008).

Approximately within the same time frame, the economic landscape of Europe started to change, due to the occurrence of two phenomena: globalization and unification of Europe. Consequently flow of materials and goods were drastically increased through liberation of trade and finance, while the innovative information technology systems facilitated management of the constantly growing cargo volumes. During this period, many non-European large enterprises, which used to have a number of plants and distribution centres scattered across Europe, decided to consolidate their activities in a single location, resulting in the rise of main distribution centres (Klapwijk, 1996).

Elements such as transportation, and total operating costs, subsidise, and living conditions, were involved in selecting a favourable location. Rotterdam was one of the main hub ports serving the northern Europe distribution centres (see Figure 6).

The 1990s was also a period when American and Japanese companies were investing heavily in establishing plants across Europe. According to Buck and Wever (1994), the Netherlands had the highest share (54%) with regard to Distribution Centres among the countries in Western Europe. This statistics reinforces the competitive advantage of Rotterdam (as the main port of the Netherlands), particularly in the provision of logistics services, in comparison with the other European locations.

Table 2- Manufacturing plants and distribution centres of American and Japanese companies in Western Europe

	High-tech prodn.	Other prodn.	R&D	EDC	EHQ
The Netherlands	10%	12%	15%	54%	26%
United Kingdom	36%	39%	28%	10%	29%
France	16%	22%	28%	8%	10%
Germany	9%	12%	23%	11%	10%
Ireland	22%	7%	2%	5%	1%
Belgium	6%	5%	4%	11%	23%
Luxemburg	1%	3%	-	1%	1%
Tot. no. of establishments	115	318	60	104	237

Source: Adapted from (BUCK and WEVER, 1994, p. 31)

During the 1980s, big shipping companies joined in alliances in order to be capable of offering different types of services to producers of goods worldwide (Kreukels and Wever, 1998). At that period, service effectiveness and service efficiency, rather than natural advantages, were the key criteria shipping lines used to select ports (Kreukels and Wever, 1998). Shipping companies, as such, played a vital role in port competition. Rotterdam reacted by 1) investing heavily in logistics and information technology, such as EDI advancements, and the fully automated Delta Container Terminal with its Automated Guided Vehicles (AGVs)(Center for Maritime Economics and Logistics, 2013), 2) engaging in hinterland connections, such as focusing more on short sea transportation, and rail in addition to road transport, and 3) transition of services from quantity to quality by initiating secondary functions in the port area, such as distribution services, storage, assembly and manufacturing.



Figure 6 - Changing distribution patterns in Northern Europe

Source: Adapted from (Klapwijk, 1996, p. 129)

In early 2000's, the Port of Rotterdam made another strategic decision to expand its international competitiveness. In a joint venture with the government of Oman, the Port of Rotterdam helped develop one of the world's largest port development projects in the Middle East - the "Port of Sohar", a deep-sea port in Oman (Port of Sohar, 2013). Port of Rotterdam was involved in port design, port construction, as well as port management and supervision. In addition to the direct benefits flowing from its cooperation with a logistics hub abroad, a number of indirect rewards, including promoting Dutch trade and industry, also materialized.

## 5. CONCLUSIONS

Over the last few decades, the Port of Rotterdam had gone through four major phases of development: 1) Maasvlakte1, 2) Distriparks, 3) Betuweroute, and 4) Maasvlakte2. Each phase was initiated by a strategy to maintain its competitiveness edges.



- First phase (Maasvlakte1, 1965-2008) was supported by a proactive strategy of physical expansion to align with the rising popularity of containerization and inter-modal transport.
- Second phase (Distriparks, 1987-1996) was essentially a reactive strategy in response to the need of container hubs, emergence of round-the-world services, storage facilities, distribution centres, and the change in distribution patterns in Europe during 1980's and early 1990's.
- Third phase (Betuweroute, 1998-2007) was the development of a double track freight railway from Rotterdam to Germany, and can be considered a combination of reactive and proactive strategies. It was a reactive policy for attracting ship-owners who were keen to switch their transport to Antwerp, and proactive in terms of contributing to modal shift (transporting more goods by more environmentally-friendly modes).
- The current and most recent phase (Maasvlakte2, 2008-2033) is an expansion project of a deep port directly on the sea, and initiated by a proactive strategy to guarantee a distinctive position for Rotterdam in the market.

In sum, the Port of Rotterdam had managed to retain its position as one of the World's top 10 container ports in the last two decades through a mix of proactive actions and responsive strategies. Each phase of its development was built upon the outcomes of its previous phases and affected the formulation of strategic actions in subsequent phases. Indirectly, the study has demonstrated that the capability building process of the Port of Rotterdam is path dependent, supported by either proactive or reactive actions.

### 5.1. Practical implications

As one of the most competitive container traffic ports in the world for the last two decades, the developmental paths traversed by Rotterdam during this period offers an exemplary case of how a global port city may navigate the changing global landscape to maintain its competitive strength. This study has helped shed light on how global port cities compete, providing valuable information for new port planning and guidelines for formulating capability building strategies for existing ports.

### 5.2. Limitations and Suggestions for Further Studies

Because this research is based primarily on secondary data and published literature, the findings are limited. The conclusion reached, as such, can only be regarded as tentative. A comprehensive analysis of the operational, tactical and strategic procedures undertaken by the Port of Rotterdam using data collection through onsite visits to port areas and interviews with Port of Rotterdam authorities and industrial stakeholders would be a logical follow-up of the present analysis.

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# **IMPACT OF MYANMAR'S DAWEI PORT ON THAILAND INDUSTRIES WITH MIXED PERSPECTIVES**

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## **ABSTRACT**

Since 2010, Myanmar has planned to develop a deep sea port at Dawei, a city in the south of Myanmar. This could result in a major change in maritime freight transport in South East Asia (SEA). That is, instead of passing through the Strait of Malacca and Singapore, sea freight between India Ocean and SEA can be unloaded at Dawei port and travelled by trucks to many cities in SEA or even reaching the south of China. This also leads to a land bridge or transport corridor connecting Dawei port to Thailand's Laem Chabang port and Vietnam's Da Nang port. Myanmar also plans to develop a large industrial estate located next to the port. This study aims to gather the points of view from Thai industries about the impact of the future Dawei port on Thailand's 5 majors industries, which are food, textiles, steel, electronics, and petrochemical. 27 companies have participated in semi-structured interviews. Based on the viewpoints given by all participants together with the extensive literature review, it is discovered that the development of Dawei port has mixed impacts on Thai industries ranging from little to high impact. Moreover, some industries will receive positive impact in some areas but will have negative impact in the other areas. All viewpoints are summarized and discussed in details in this paper.

## **INTRODUCTION**

In 2010, Myanmar government has decided to develop a deep sea port at Dawei, a city in the south. This could result in a major change in maritime freight transport in South East Asia (SEA). That is, instead of passing through the Strait of Malacca and Singapore, all international freight traveling between the India ocean and the south of China can be unloaded at Dawei port and travelled by trucks to many cities in SEA or even reaching the south of China e.g. Kunming. This also leads to a land bridge or transport corridor connecting Dawei port to Thailand's Laem Chabang port and Vietnam's Da Nang port. Myanmar also plans to develop a large industrial estate located next to the port.

## **RESEARCH OBJECTIVE AND METHODOLOGY**

This research aims to gather the points of view about the impact of the future Dawei deep sea port on Thailand industries from both primary and secondary sources of data. To choose which industry to be included in this research, the export statistics of Thailand in 2011 is used. Then, the top 10 products exported to only Europe, Africa, and the Middle East are identified since the availability of Dawei port would probably have more impact on Thai products en route to these destinations than the other parts of the world. These top 10 products can be categorized into 5 major industries which are food, textiles, steel, electronics, and petrochemical.

To obtain the primary data, the authors have conducted numerous semi-structured interviews. Initially, 50 companies and organizations related to the 5 major industries were invited. Only 27 of them joined the individual interviews. The number of interviewees from each industry: food, textiles, steel, electronics, and petrochemical industries are 6, 3, 4, 4, and 3 respectively. There are also 5 interviewees from universities and government organizations, and another 2 interviewees from logistics service provider companies. Each interviewee was asked to give their opinion about the possible impacts of developing the Dawei port on their associated industry with a similar set of 10 open-end questions. In addition to the in-depth interviews, the authors have obtained the secondary data by reviewing more than 100 articles published in Thai language ranging from the research papers to the articles in the newspapers and websites. The result from both interviews and literature review can be summarized into 6 areas. They are (1) raw material acquisition, (2) change in Myanmar workforce, (3)

financing in Myanmar, (4) energy infrastructure in Myanmar, (5) change in transportation route, and (6) market expansion opportunity. The possible impact on Dawei port on the 5 industries in each area is discussed as follows.



Figure 1. Land transport via Myanmar’s Dawei port compared with sea transport via Malacca Straits and Singapore

### RAW MATERIAL ACQUISITION

Dawei port will have a positive impact on Thailand’s steel industry as it can make use of Myanmar’s rich natural resources of iron ore. However, it is necessary to analyse whether the quality and specification of Myanmar iron ore is up to the required standard and matches with the need of Thailand’s usage. Myanmar is also rich in natural oil and gas which will give benefit to Thailand’s petrochemical industry if Dawei port is in operation (Polasen, 2012). But this depends on how Myanmar manages the effect of pollution on the environment, and handles the resistance from the affected community. Since Thailand imports cotton and yarn about 90% of its total demand, the textile industry will definitely reap some benefit as the port will allow Thailand to import cotton and yarn from India and Pakistan at lower transshipment cost and delivery time. Thailand’s electronics industry heavily relies on the import of electronics parts from many parts of the world. Therefore, Dawei port can lower the cost of transshipment for the industry. In addition, if the transportation infrastructure between the south of China and Myanmar can be improved, Dawei port would be an important gateway for the electronics industry to import Chinese electronics parts and supplies at lower transportation cost and time. Unlike other industries, Dawei port will have little impact on the food industry as Thailand has sufficient natural resource with higher quality. Thailand also has the different food processing standard from Myanmar.

## **CHANGE IN MYANMAR WORKFORCE**

Migrant workers from neighbouring countries like Myanmar, Cambodia, and Laos make up as much as 10% of Thailand's workforce (Wallace, 2013). As for Myanmar workers, there are about 2.5 million workers with legal work permit and another 1 million workers with no legal work permit. There is a consensus of viewpoints from all industries that the opening of Dawei port will cause some Myanmar workers currently working in Thailand to relocate and work inside Myanmar especially at the industrial estate next to Dawei port. However, the higher salary in Thailand still attracts more and more new Myanmar workers to go to work in Thailand. All 5 industries report many similarities. There is a shortage of skilled workers in Thailand. It is also difficult to train and improve the skills of Myanmar workers. In petrochemical industry, it is difficult to train Myanmar workers due to lack of engineering skill. In electronics industry, Myanmar workers lack of accuracy and precision in assembling electronics parts. Thai companies also have problems retaining Myanmar workers. For textiles industries, there is a possibility that some Thai manufacturers of low-quality garment will relocate its production line to Myanmar especially near the border of Myanmar and Thailand. But the production of high-quality garment still remains inside Thailand as Thai workers have better skill than Myanmar (Srisupornwanich, 2012). However, Myanmar workers still play an important role in Thailand's food industry as high skill is not required. But in the future as more and more machines and automation replace human in food processing, skilled workers to control the machine are more needed and unskilled workers will be less needed.

## **FINANCING IN MYANMAR**

All Thai industries agree that Myanmar still has unstable financial and banking system. Thai investors will have to use the funding from Thai banks if interested in investing in Myanmar. But it is difficult for Thailand's steel industry to relocate its production to Myanmar as the nation still does not have enough supporting upstream industries for the steel production. Both textile and electronics industries recently experience the difficulty of obtaining finance from Thai banks to invest inside Thailand so it is even more difficult for both industries to invest and expand its production to Myanmar.

## **ENERGY INFRASTRUCTURE IN MYANMAR**

All 5 Thai industries also agree that Myanmar still does not have sufficient electricity production capacity for both industrial and household demand. The nation still lacks of national policy in energy development. In particular, it is difficult for the industries using large machine and equipment such as steel and textile industries to relocate and expand in Myanmar (Aran, 2011). However, it is very likely for the petrochemical industry as there have already been some Thai companies being granted to utilize natural gas in Myanmar. So it is expected that Myanmar's abundant natural gas will be the key player to improve Myanmar's electricity capacity. Food industry also reports a lack of efficient water supply which makes it difficult to develop food production in Myanmar.

## **CHANGE IN TRANSPORTATION ROUTE**

There are extensive and mixed viewpoints about the impact on transportation from 5 industries. Food industry sees the clear benefit of lower transportation cost to Europe through Dawei port. But there is a concern that the poor quality of road from Thailand to Dawei port that could prevent the transportation of cold and frozen food. Textile industry also expects the improvement in transportation because many textile and garment factories are located near the borderline between Thailand and Myanmar. Therefore Dawei port is a good choice to export to Europe and the Middle East compared to Thailand's Laem Chabang port with chronic traffic congestion problem. Steel industry reports the little impact or benefit of Dawei port in transportation. Because the majority of steel plants are located near Laem Chabang port so it does not see the likelihood of truck transportation between Thailand and Myanmar and the use of Dawei port as the connection to the sea. Moreover, Thailand's steel industry production capacity mostly goes for domestic demand, rather than for export. Electronics industry has a concern about the poor quality of road transportation between Thailand and Myanmar as electronics products are fragile and shock-sensitive. There is also a trend that more and more electronics products are exported by air via Thailand's Suvarnaphumi Airport. Therefore, it is less likely for electronics industry to transport through Dawei port in the

future. As for petrochemical industry, Dawei port probably has the impact on transportation route for those plants and companies located near Myanmar. For those plants and companies in other part of Thailand, Laem Chabang port is still a better choice.

### **MARKET EXPANSION OPPORTUNITY**

Both food and textile industries confirm the great opportunity to export their products to Europe, the Middle East, and Africa through Dawei port. Textile industry reports the possibility of expanding its production at the industrial estate near Dawei port with the attention to produce high quality product to compete with Chinese products in Europe market. Both steel and electronics industries see less market opportunity with the availability of Dawei port as most customers of steel industry are domestic and located near Laem Chabang port. The capacity of Thailand's petrochemical industry is generally to support the domestic demand and neighbouring countries. Therefore, Dawei port will have little impact on expanding the market of petrochemical industry.

### **CONCLUSION**

Dawei port has been a centre of attention in Thailand since 2010. There has been uncertainty in both the port construction project and the possible impact on Thailand industries. This paper has thus gathered the viewpoints of Thailand's 5 major industries through both in-depth interviews and literature reviews. The results from 27 interviewees and more than 100 articles published in Thai language are analysed and summarized. Most industries in Thailand will receive benefit from Dawei port as a gateway to acquire raw material. Dawei port project will have some impact on the movement of Myanmar workforce in Thailand. Poor financial system and underdeveloped energy infrastructure in Myanmar will hinder the investment and capacity expansion of Thailand industries inside Myanmar. Thai industries that frequently export its products to Europe and the Middle East will reap a great benefit in using the faster route via Dawei port and also in expanding the market opportunity in the western.

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## **Section 7 – Transport, Distribution and Third/Fourth Party Logistics**

### **PERFORMANCE EVALUATION OF MIXED-LOAD RAIL-GUIDED VEHICLE SYSTEMS**

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#### **Abstract**

This research evaluates mixed-load vehicles that provide transportation support to a pull-controlled production system. A mixed-load vehicle has two storage decks. Heavy WIP must be stored in the upper deck. The lower deck stores only lightweight materials. We run simulation to estimate the number of vehicles required to achieve the maximum output. The result is then compared with single-load and double-load vehicles. Our analysis suggests that replacing single-load vehicles with mixed-load vehicles can reduce the number of vehicles by at least 30%. We also observe that mixed-load vehicles perform almost equally to more expensive double-load vehicles. By showing that a mixed-load vehicle system can better support the proposed production system, our study helps validating the application of mixed-load vehicles.

#### **Introduction**

Rail-guided vehicle systems (RGVS) are widely implemented in manufacturing and logistics systems. Vehicles travel on rail and transport work in process or inventory to multiple destinations. A well-designed RGVS provides an economic solution to improve efficiency of material handling and performance of the system it supports. If a RGVS fails to provide adequate support, Sinriech and Kotlarski(2002) suggest several options for improvement. The first option is adding more vehicles, which could create traffic congestion. Another option is increasing vehicle speed, which could result in danger of collision. The third option is using multiple-load vehicles that can carry two or more loads at the same time. Blige and Tanchoco(1997) advocate that using multiple-load vehicles is less risky and reduces the number of vehicles required to support the operations.

This study is motivated by our visit to a metal fasteners packaging facility in Kaohsiung. A RGVS is responsible for moving fasteners, metal containers, and packaging materials. The initial design by the equipment provider used single-load vehicles. Then the management proposed a switch to double-load vehicles in anticipation of market growth. The change would require major modifications to the mechanical structure and the vehicle power

system. It would also increase the installation cost substantially and delay the entire project. Eventually, the management settled on a compromise to use mixed-load vehicles.

A mixed-load vehicle is modified from a single-load vehicle. It has two storage decks but functions differently from a double-load vehicle. Due to weight limitation and loading height requirement, heavy WIP and metal containers must be stored in the upper deck, while the lower deck stores only supply materials or packed products. Its design is a compromise between vehicle cost and carrying capacity. We want to evaluate the application of mixed-load vehicles in a RGVS t and to compare with single-load and double-load vehicles.

### **Literature Review**

Most of the RGV literature considers single-load or double-load vehicles. We are not aware of any studies on mixed-load vehicles. Bilge and Tanchoco(1997) suggest that using multiple-load vehicles in a job shop environment can reduce the deadhead or unproductive time of vehicles and the total distance traveled, making a smaller fleet size possible. Aside from savings in investment, this will allow enjoying the merits of smaller unit-load sizes without suffering serious congestion and communication problems. Their simulation results show that, with multiple-load vehicles, the sensitivity of AGV system performance to guide-path layout is decreased, and the job input rate is significantly increased.

Sinriech and Kotlarski(2002) develop a dynamic scheduling algorithm for a manufacturing system arranged around a single loop serviced by several multiple-load carriers. Simulation results show the algorithm outperforms three scheduling rules. It is able to achieve the same throughput performance with a much smaller WIP level and a shorter cycle time. They also point out that one of the major issues that arises from the use of multiple-load carriers. Assuming a fixed amount of carrying capacity is used, should one employ a small number of carriers, each with a large carrying capacity or a larger carrier fleet each with a smaller carrying capacity?

Le-Anh and De Koster(2006) present a review on design and control of automated guided vehicle systems. They address key issues including guide-path design, determining vehicle requirements, vehicle scheduling, idle-vehicle positioning, vehicle routing, and deadlock resolution. They state that multiple-load vehicles are expensive, but may reduce the number of vehicles needed or increase the system throughput. They also point out that the number of vehicles is strongly affected by the dispatching rules used and there are still lack of studies which develop efficient scheduling and dispatching algorithms for multiple-load vehicles. Kim and Chung(2007) present an analytical model to design a tandem automatic-guided vehicle (AGV) system with double-load vehicles. The design procedure



consists of two steps: the 'selection of feasible zones' step and the 'selection of the final guide path' step. They suggest using simulation to compare the performance of a tandem AGV system with multiple-load AGVs with that of a conventional AGV system.

In recent years, there have been studies on controlling multiple-load vehicles to improve the production efficiency in a TFT-LCD manufacturing environment. Ho and Liu(2006) conduct simulations to compare pickup-dispatching rules for multiple-load vehicles. Their results suggest that dispatching vehicles to the station with the greatest output queue length performs better than distance-based or due-date-based rules in all performance measures. Ho and Liu(2009) continue their previous work and find that the load-selection rule based on the destination similarity between loads has the best throughput and tardiness performance. Simulation results also indicate load-selection rules and pickup-dispatching rules affect each other's performance. Yang and Shen(2011) study AGVs carrying glass substrates that are stored in a cassette. They combine simulation and a neural-network based methodology to determine a dynamic transfer batch-size strategy within a volatile production environment. The results show that the dynamic transfer batch-size is superior to the fixed batch-size transportation.

### Research Design

We develop simulation programs to model a single-loop RGVS with various types of vehicles to support parallel workstations with pull control. The model is based on a fastener packaging facility in Kaohsiung that we have visited several times. It has a single-loop RGVS system with vehicles moving uni-directionally between an AS/RS, four semi-automatic machines, four fully-automatic machines, a packaging material supply station, a shipping station, and an empty container retrieval station. Figure 1 illustrates the basic layout.

→ Figure 1: A single-loop RGVS and the shop floor layout.

The operation starts with the control system directing the AS/RS to retrieve a container of fasteners to be processed by the designated machine. A vehicle is dispatched to deliver the container to the position of that machine. At the same time, the supply station will load packaging material to another vehicle and deliver to the same machine. If the machine is ready for processing, the container is moved to the position to feed the machine. An operator sets up the packaging material and starts the machine to process all fasteners. Upon completion, the operator requests a vehicle to transport the finished product to the shipping station and another vehicle to send the empty container to the retrieval station. Although the control system has planned the processing sequence and job assignments, dispatching of jobs is activated by operators working on the shop floor. An operator will

push a button to request a new job as long as there is available space in the storage area. This is similar to the concept of pull control. Most RGV studies assume push control.

A mixed-load vehicle has two storage decks. Heavy WIP or metal containers are stored in the upper deck. The lower deck stores only supply materials or packed products. It costs nearly the same as a single-load vehicle. A double-load vehicle is more expensive. It has a similar design but do not have loading constraints. It can pick up two containers at the AS/RS and deliver to different destinations. Figure 2 illustrates the flow of transportation performed by all types of vehicle. Fasteners stored in a container are moved from the AS/RS to machines. Packaging materials are moved from the supply station to machines. After processing, finished products are sent to the shipping station and empty containers are returned to the retrieval station. Notice that processing one unit of product with mixed-load vehicles requires four trips, two in the upper deck and two in the lower deck.

Figure 2: Transportation of material in and out of machines.

We have modified the parameters used in the experiment for confidentiality reasons. We set processing rates of the AS/RS and the packaging supply so that both stations will not slow down the system performance. Other parameters include:

- (1) Traveling times: 0.36 minutes from retrieval to AS/RS and from the nearest machine to packaging supply. 0.12 minutes between any other adjacent stations.
- (2) Loading/unloading times: 0.25 minutes at any station.
- (3) Processing times (minutes): Triangular(10,12,14) distribution for semi-automatic machines and triangular(6,8,10) distribution for fully-automatic machines.

The maximum output of the current system is 50 units per hour. We run simulation to estimate the number of vehicles required to achieve the maximum output. Experimental factors include type of vehicle, number of vehicles, and number of machines. We define key performance measures as follows.

- (1) Output rate per hour: Average number of packed products delivered to the shipping station per hour. This is the main concern of the management.
- (2) Percentage of throughput loss: Difference between actual output and maximum output. An operator may stop the machine and wait for a vehicle to make delivery or to pick up completed work. This is the main concern of operators who are paid based on output.
- (3) Percentage of time in congestion: Percentage of time a vehicle is stopped by other vehicles performing loading or unloading operations. A high percentage indicates too many vehicles deployed in the system.

(4) Average WIP: Include all fasteners sent out by the AS/RS and yet to delivered to the shipping station. The management prefers a small WIP if the output rate remains high.

### Simulation Analysis

We have developed several simulation models using Arena 14.0. The replication length is 120 hours, with the first 20 hours excluding from statistical collection. We replicate each run 30 times in order to compute confidence intervals of the performance measures. All errors are within 0.5% of the average values.

We first evaluate the performance of a single-load vehicle system by varying the number of vehicles. Simulation results suggest that at least six vehicles are needed to reach the maximum output. Then we repeat the experiment using mixed-load vehicles and observe that four vehicles are sufficient to guarantee the maximum output. The facility we visited has a similar situation. It bought five vehicles but the manager soon decided that only four were needed and moved one vehicle to the storage room. Another experiment investigates what would happen if expensive double-load vehicles are used. Figure 3 shows that double-load vehicles have almost identical performance as mixed-load vehicles.

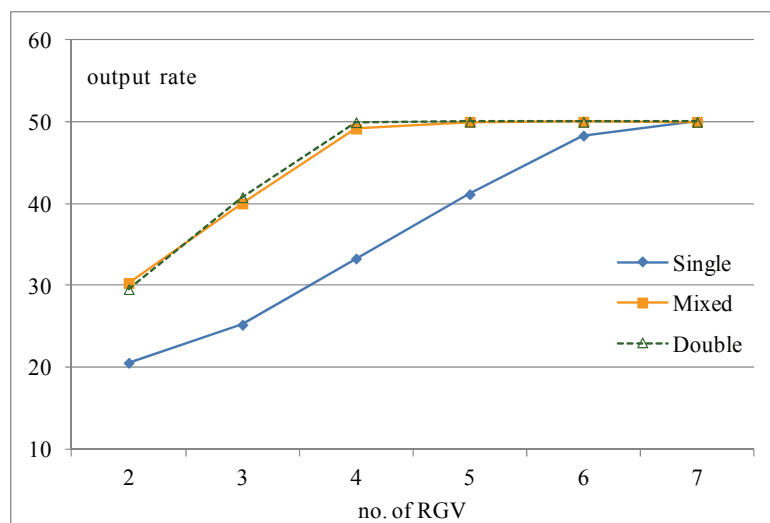


Figure 3: Number of vehicles versus output rate in an 8-machine system.

These experiments suggest that double-load vehicles have no significant advantage over less flexible mixed-load vehicles. A possible explanation is that the system we study has equal transportation requirements for heavy WIP/containers stored in the upper deck and supply materials/packed products stored in the lower deck. This reduces or eliminates the advantage of the flexibility possessed by double-load vehicles. The performance of a mixed-load system may deteriorate if transportation requirements are unbalanced.

Given a fixed amount of carrying capacity, we observe that a system with 6 single-load vehicles has an output rate significantly higher than a system with 3 mixed-load or double-load vehicles. Under these operational conditions, our answer to the question proposed by Sinriech and Kotlarski(2002) is that single-load vehicles are better. But the costs are significantly different.

Since the future expansion is an important factor in the decision process, we next consider a 12-machine production system. The maximum output increases to 75 units per hour. It also takes longer for a vehicle to travel a loop. Simulation results show that the system needs more vehicles to reach its full capacity. It takes 12 single-load vehicles to reach the maximum output. Mixed-load vehicles perform very close to double-load vehicles. Both need 8 vehicles to attain the maximum output. The results also show that a fleet of single-load vehicles can better support the production system than a fleet of mixed-load or double-load vehicles with the same carrying capacity.

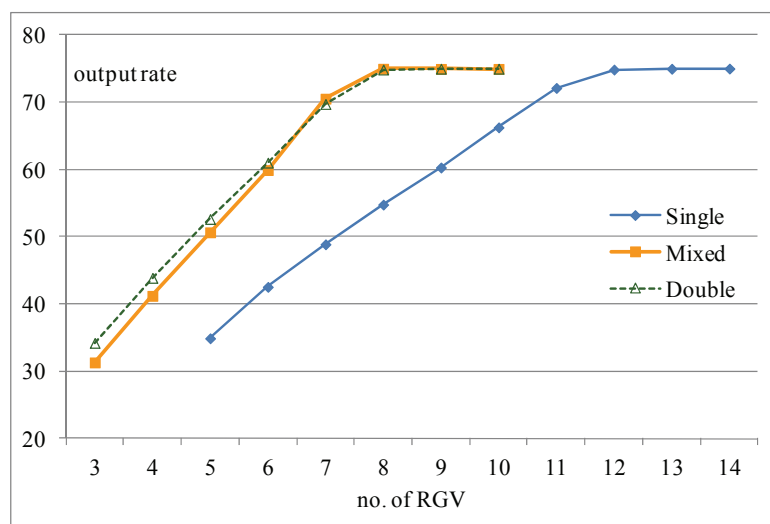


Figure 4: Number of vehicles versus output rate in a 12-machine system.

One of the merits of using multiple-load vehicles is to avoid traffic congestion. We next compare work in process inventory of fasteners using different types of vehicles. Figure 6 plots WIP against the actual output rate and shows that single-load vehicle systems have more WIP even when the output rate is low. Mixed-load vehicle systems have significantly less WIP. Applying Little's law suggests that mixed-load systems are less congested and have shorter waiting times for vehicles. Note that a mixed-load vehicle cannot carry two empty containers or two units of packaging material. This may be one of the reasons that a load of fasteners does not wait long to be moved.

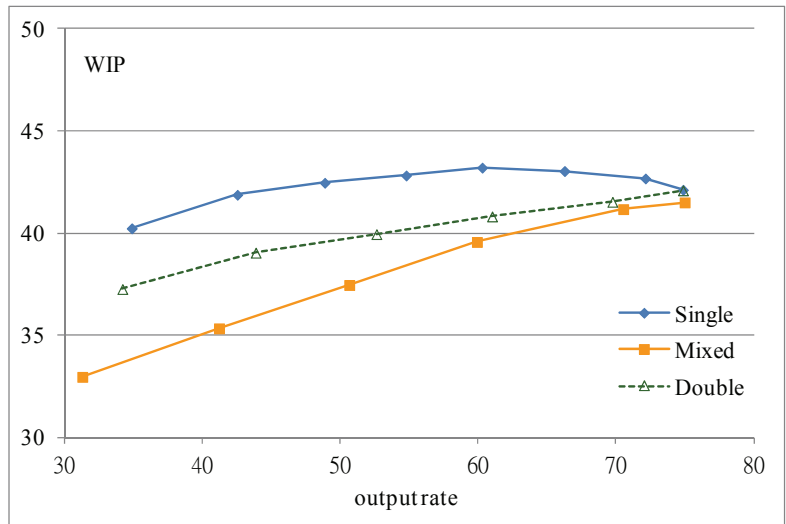


Figure 5: Output rate versus WIP in a 12-machine system.

The following figure plots the percentage of congestion time versus the actual output achieved. It suggests that a mixed-load vehicle system has less traffic congestion than the other systems, while achieving equal or higher output rate. We are surprised to find that double-load vehicle systems have almost as much congestion as single-load vehicle systems. A possible explanation is that a double-load vehicle is more likely to perform two unloading and two loading operations at the same station. This creates more variable stoppage time at a station and more congestion.

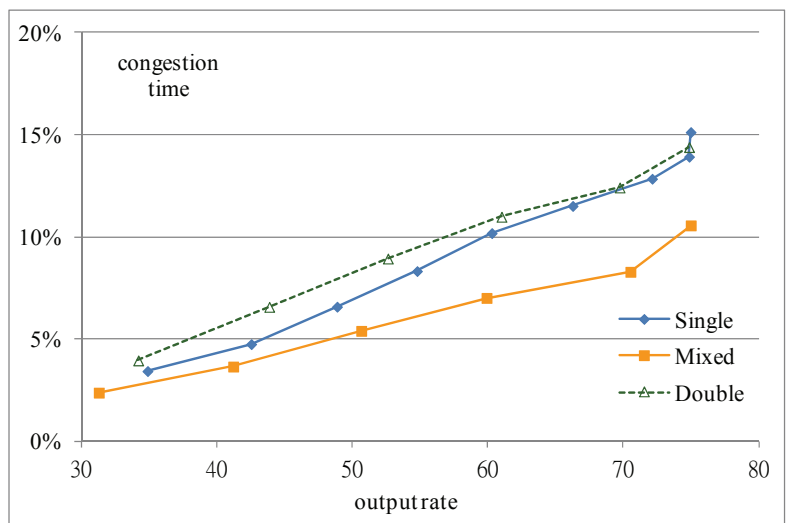


Figure 6: Output rate versus congestion time in a 12-machine system.

**Summary**

A RGVS is a major investment and is critical to the performance of a manufacturing/logistics system. There have been many studies on the design and application of multiple-load vehicle systems. We believe our study is the first one on mixed-load vehicle systems. A mixed-load vehicle costs about the same as a single-load vehicle, but using a mixed-load vehicle system reduces the number of vehicles required by

at least 30%. It also results in less congestion and less WIP. Although performing slightly behind a double-load vehicle system, a mixed-load vehicle system does not require more powerful motors and more sophisticated material handling device. These observations are based on the operational conditions we assume, but the setting is quite common in the manufacturing environment.

Like any multiple-load systems, a mixed-load system also requires careful planning of task selection and vehicle dispatching. Our preliminary study finds that, if the number of vehicles is not enough to reach the maximum output, implementing a dispatching rule that considers different types of loading requests can increase the output rate by about 5-10%. We will continue to develop dispatching rules incorporating types of loading requests and the status of a workstation to improve the performance of a mixed-load RGVS.

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# REENGINEERING OF TERMINAL PROCESSES IN INLAND CONTAINER TERMINAL

**Suggested topic area:** Case study

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## ABSTRACT

Inland container terminals represent an important part of modern intermodal transport. The operational capability of entire intermodal supply chain depends on the operational capability of these terminals. Therefore, special attention should be given to the improvement of terminal processes operability. The main research question in this contribution is how business process modelling and reengineering can be used in reengineering terminal processes in inland container terminals. Modelling of business processes is very important activity in both management and utilization of resources in particular working system. In business logistics micro-and meta-systems, processes can be represented as a series of related logistics activities, which are created using the resources of the working system in order to create value for the consumers.

This paper focuses on modelling and simulation of the basic terminal processes in inland container terminal. The ultimate goal is to identify the weaknesses and potential problems in the execution of current logistics activities, as well as in reengineering, those identified weaknesses and problems. For this purpose, in this paper we used a case study of the railroad container terminal ZIT Belgrade, and create two simulation models: the model of the current ("AS-IS") and the model of improved ("TO-BE") state. The efficiency of logistics processes in this simulation models, is monitored by time that container spent in terminal, resource utilization and total operating costs.

Main contribution of this paper is in novelty approach in rationalization of logistics processes in inland intermodal terminals. Creating models of current ("AS-IS") and improved ("TO-BE") state, it is shown that simulation, represents an easy accessible and effective tool in analysis of terminal processes in container terminals. Therefore, it can be efficiently used for monitoring of the current situation, identification of the weak points in particular system, and for creating a necessary preconditions for business processes improvement.

**Keywords:** logistics processes, intermodal terminals, containers, simulation modelling.

## **INTRODUCTION**

Intermodal transport represents the main link in modern global economy. Without efficient and economically profitable combined transport, the world economy would not be on the current level of expansion. This development has been driven by progressive globalisation and the intensification of the international division of labor (Grossmann, Otto, Stiller, & Wedemeier, 2006). On the other hand, one of the key globalisation drivers was the onset of containerization. Use of container as "hardware" have revolutionized global trade, but in allowing for a box to be transferred from one mode of transport to another, containerization also became the "software" allowing for true intermodalism - the coordinated flow of goods over long distances using different modes (Sawyer, Fuqua & Kulick, 2005). Efforts to establish a fully manageable, cost effective and reliable intermodal transport is one of the main pursued goals, in order that to global economy could continue developing in the current pace. Since of the efficiency of the terminals, which are spaid to intermodal terminals, as areas of concentration of cargo flows and confrontation of various modes of transport. The major challenge for container terminals is how to successfully handle the escalation in container traffic demand? Hence, container terminals are in constant searching for solutions to manage additional demand, other ways, they risk losing business to their competitors. Simulation models are well applicable due to stochastic and dynamic nature of container terminal processes. In the last several years discrete event simulation models in the object oriented approach have been proposed as decision support systems, with reference to container terminals. The object oriented approach has been particularly useful to describe logistic operation of the main system terminal modules (Assumma & Vitetta, 2006). Accordingly, this paper deals with the modeling and simulation of basic logistics processes at the container terminal as a possible answer for specified problems. The aim of this study is to describe the real logistics business processes and create conditions to determine possible weaknesses in functioning of the existing system (AS IS model), and to develop the model of improved condition, which remedy deficiencies (TO BE model). For this purpose, we used a case study of mainland container terminal ZIT Belgrade.

## **CONTAINER TERMINALS**

### **Intermodal transport and containerization**

Intermodal transport represents transportation technology in which goods movement is performed by means of intermodal loading units (e.g. containers, swap bodies, trailers) that are not subject to deconsolidation during the entire transport chain. Intermodal



transport may be viewed as an alternative to unimodal transport in the case of long travel distances and high volumes. Intermodal transport efficiency and competitiveness with respect to full-road transportation lie essentially in the lower transport costs that can be achieved in the central part of the trip (i.e. by rail or sea), but also highly depend on the efficiency and effectiveness of the activities performed within the network 'nodes' (i.e. ports or intermodal terminals) (Marchet, Perotti, Mangiaracina & 2011). Containerization can be considered as the industrial revolution of the general cargo transportation and handling methods and as an activator of full intermodalism, started with Malcolm McLean and his company Sea Land (<http://hbswk.hbs.edu/item/5026.html>). The main reason for implementing intermodal transportation in global flow of goods could be explained by a tendency toward rationalization of the entire transport process between sender and receiver. Containerization and intermodality revolutionized and redefined the modern shipping, ports and, at a later stage, inland transportation.

### Port and inland container terminals

Container terminals are the most important links of the modern intermodal container transport. The principle of the modern container transport chains is a network of container terminals that are interlinked by high capacity transport routes and are used as a points of transfer between different transport modes. In essentially container terminals are logistics hubs, whose capability of handling requests and attributes that are facing in terminal, represents their basic measure of competitiveness. There are two major types of container terminals: port and inland container terminals. Port container terminals are key hubs of global supply chain networks and they role, as a seamless intermodal interface between marine and overland transportation, is to stevedore and store containers (Ha, Park & Lee, 2007). Port container terminals can be described as an open system of micro logistics flows, which are connected with environment (macro logistic flows), by two buckles. These buckles are port docks, charged for loading and unloading ships, and inland parts of the port where containers are loaded and unloaded with ground vehicles, Figure 1.

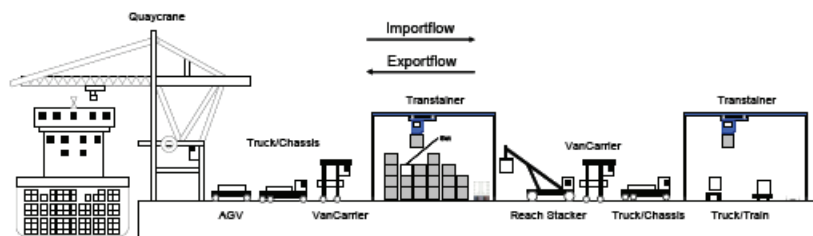


Figure 1: Containers flow in port container terminal

The port container terminals is generally found in one or both of two types of ports - a transshipment hub designed to optimize the transfer of containers between network long-haul trunk lines and/or between trunk and feeder lines; or a gateway port designed to

serve the needs of local, regional, and sometimes large inland populations (Brooks, 2011). The productivity of the modern port container terminal is highly dependent on its equipment, yard configuration, processes organization and strength of hinterland connectivity. Even more, connection with hinterland could be one of the major bottleneck, because of congestion and reliability problems. Hence, there is a necessity for searching a new container chain organization and solutions through the development of modern inland container terminal facilities to relieve arising congestion in port areas, rationalize the pattern of inland freight movement, enlarge the port hinterland and attract additional traffic (Iannone, Thore & Forte, 2007). Inland container terminals represents a facility located in the hinterland of one or more seaports, where different services are available to carriers and shippers, such as: container stuffing and unstuffing, rail-road transshipping, temporary storage of import/export full and empty containers, customs clearance and inspection, container tagging and sorting, container repair, manipulation and processing of the containers' content for later marketing efforts at ultimate destinations (Iannone, Thore & Forte, 2007). Inland container terminals have an important role in the distribution of containerized goods to the inland, and due to that they have a significant influence on the industrial development of the region. A special form of land container terminals are road-rail terminals. The basic types of cooperation between road and rail transport in road-rail intermodal terminals are unaccompanied and accompanied combined transport. Unaccompanied transportation is the transportation of loading units of intermodal transport (e.g. containers, swap bodies, trailers), Figure 2, and by European Commission, this form of transport participates with 86% of the total combined transport between road and rail (<http://www.uirr.com/>).

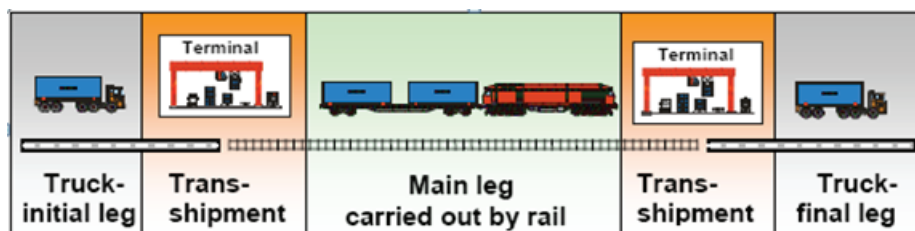


Figure 2: Unaccompanied transportation

In existing port terminals there are often problems of space and traffic constraints because it is not possible to expand to the surrounding areas. Hence, a new logistic network systems which assumes dedicated rail connection between port yard and inland terminals are needed. Because of that, inland container terminals are gaining increasing importance in the global logistics networks, and therefore particular attention in terms of their planning, organization and processes optimization must be given to them.

## **CASE STUDY**

The case study was carried out on the example of inland container terminal ZIT Belgrade. ZIT Terminal is the largest and most significant container terminal in the Republic of Serbia, and it is located in the main railway station in Belgrade. Presented case study is a continuation of research on the possibilities of implementation and benefits, obtained by modeling and simulation of business processes in a container terminal. Research has begun in 2011, by developing of AS-IS model for ZIT terminal (Mircetic, Stojanovic & Maslaric, 2011). In this paper research was continued by creation of TO-BE model, and together with AS-IS model, completes research on the reorganization of container terminal using simulation and modeling methods.

### **Development of the AS-IS model for ZIT terminal**

Terminal ZIT consists of several work sectors, which carry out various business and logistics activities necessary for container flow through the terminal. The most common flows of work activities that are executed in the terminal ZIT consists of following: on the arrival in the container in terminal, the receiving sector forwards notice about the arrival to the administrative sector. Dispatcher in the administrative sector, gives orders to release the container in the operating sector of terminal. Further technological process of the containers movement through the terminal depends on whether the containers must be immediately dispatched from the terminal (direct transshipment), or containers need to be stored in warehouse. If arrived containers were intended for direct shipping, containers are loaded on trains or road haulers, while containers intended for storage, are unloaded in the operational zone of crane and diverted to the warehouse sector. Containers are usually stored in warehouse, due to waiting for the formation of collective container deliveries (indirect transshipment). Containers unloaded in the operation zone of the cranes, are lifted up by forklifts and delivered to the warehouse sector. Dispatching containers from warehouse are also done by forklifts, where containers are picked up from warehouse and transported to the operation zone of the crane. Crane then lifts up containers and perform their loading on trains or road haulers. Loaded containers are registered by the dispatcher and dispatched from the terminal. On the base of the previously description of business processes in the terminal, modeling and simulation were carried out using iGrafx software, and as a result AS-IS model, of current condition of container terminal ZIT, was formed, Figure 3. While forming the AS-IS models, several other data were used: data on the internal structure of the company and the container turnover per year, data about employed persons, their work activities, time and cost of performing certain activities, as well as data about employed wages and the costs generated by the use of machinery[6]. Simulating the current situation with AS-IS model, for period of one year, transit time of containers is determined, and shown in Table 1. Based on the Table 1, it is obvious that the storage sector is dominant in terms of time that containers spend in it. Time that containers

spent in waiting for resources is on the significant level. This time is especially dominant in the warehouse sector, and represents requests for a dispatching container when resources are out of work or request is made out in weekends. Simulating the usage of available resources of AS-IS model, obtained the distribution presented in Figure 4. The presented simulation data on Figure 4, shows that best utilized resources in ZIT terminal are crane and crane operator with 63.45% utilization, while other resources are on the inadequate level of utilization, regarding their technological capabilities. The total cost incurred due to the salaries for workers and expenses related to the use of manipulative machinery in AS-IS model is 26 163 euros.

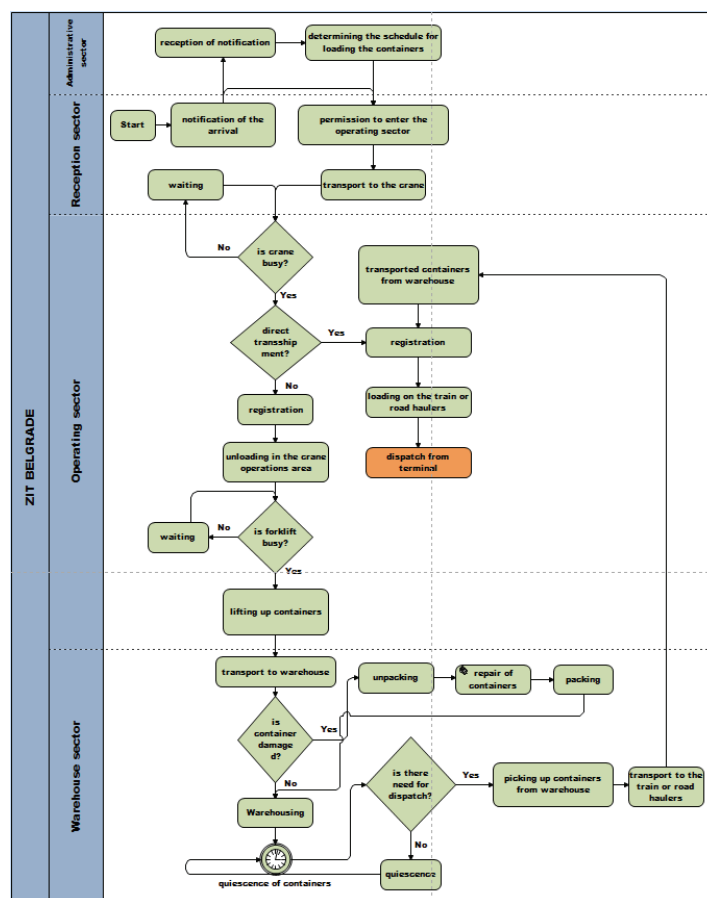


Figure 3: AS-IS model of terminal ZIT

Sectors	Num. of Containers	Average cycle time (min)	Average work time (min)	Average waiting time for resources (min)	Average waiting time when resources are out	Average warehousing time (min)	Average time spent in handling containers (min)

					the schedul e (min)		
Administrat iv	4119	3	2	1	0	/	2
Operating	4119	33	15	17	1	/	15
Reception	4119	12	7	4	1	/	7
Warehouse	1023	3751	43	16	812	2880	2923

Table 1: Transit time distribution of containers in work sectors of AS-IS model

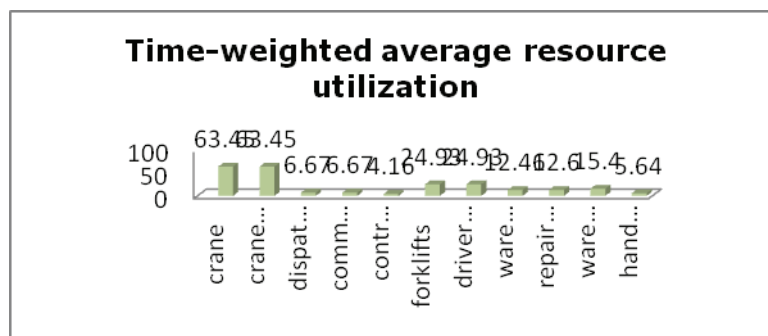


Figure 4: Resource utilization of AS-IS model

### Identification of the problem spots

AS-IS model, identified certain problem spots in the organization of business processes in the terminal ZIT:

- The lack of a unique and comprehensive database about container flows and positions in the container terminal.
- Ineffective flow of information between the reception sector and administrative services, which results in the retention of container in the reception sector of terminal. Average waiting time for containers in the reception sector is 12 minutes, Table 1.
- The lack of modern information system.
- The lack of systematic planning of containers flows in terminal. Consequences of this are reflected in the inadequate utilization of available resources, Figure 4.
- Time that containers spent in waiting for the resources is on the significant level, and sometimes containers spent more time in waiting, then in handling by particular resource, Table 1.

### Development of the TO-BE model for ZIT terminal

While developing the model of the improved state (TO-BE model) some organizational and structural changes were carried out, compared to AS-IS model. The changes are based on

the introduction of modern information systems in the terminal, as well as the reorganization of certain work processes and operations. When developing model of the improved situation, several models were developed. These models were compared with each other and evaluated. Presented TO-BE model is the optimal model according to the criteria of the overall improvements and cost savings that can be realized by implementation of TO-BE model in the container terminal ZIT, Figure 5. In TO-BE model, the role played by administrative sector in AS-IS model is fully transferred to the information system based on Radio frequency identification technology (RFID). The problem that existed in the warehouse sector, and was related to dispatching the containers from terminal during weekends, is solved by the introduction of another work shift on Saturdays. In TO-BE model, containers that arrive on road haulers, are unloaded by forklifts, and containers which have arrived on trains compositions are unloaded by crane. From Table 2 is clear that the TO-BE model shows a reduction in the transit time of containers in all working sectors except in the operational, Table 2. The increase in the in operational sector happens because of larger number of work activities that take place in TO-BE model, relative to the number of work activities in the operational section of the AS-IS model. Also, it can be seen that the Average waiting time when resources are out of the schedule, is significantly reduced, and now are 361 minutes. Simulating the usage of available resources of TO-BE model, obtained the distribution presented in Figure 6. From Figure 6 it is evident that distribution is much more balanced compared to AS-IS distribution, Figure 4. We can see remarkable change in utilization of forklifts, whose utilization now amounts 48.08%, compared with 24.93% utilization of forklifts in AS-IS model. Also TO-BE model generated smaller total costs, and they are 21 225 euros.

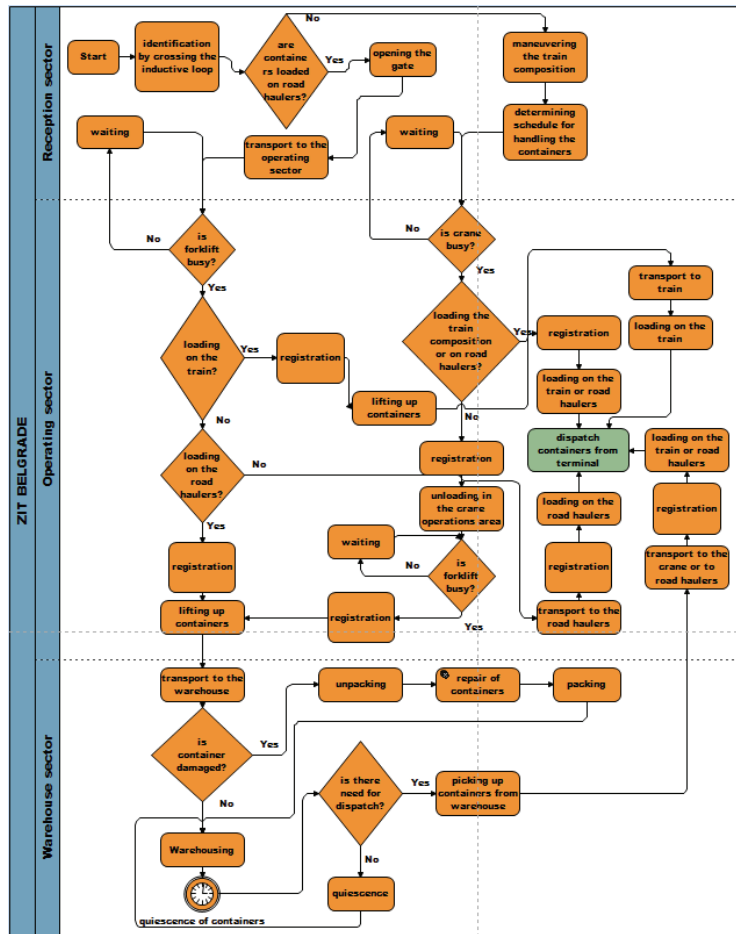


Figure 5: AS-IS model of terminal ZIT

Sectors	Num. of Containers	Average cycle time (min)	Average work time (min)	Average waiting time for resources (min)	Average waiting time when resources are out the schedule (min)	Average warehousing time (min)	Average time spent in handling containers (min)
Operating	4119	33	19	14	0	/	19
Reception	4119	1	1	0	0	/	1
Warehouse	1023	3289	39	9	361	2880	2919

Table 2: Transit time distribution of containers in work sectors of TO-BE model

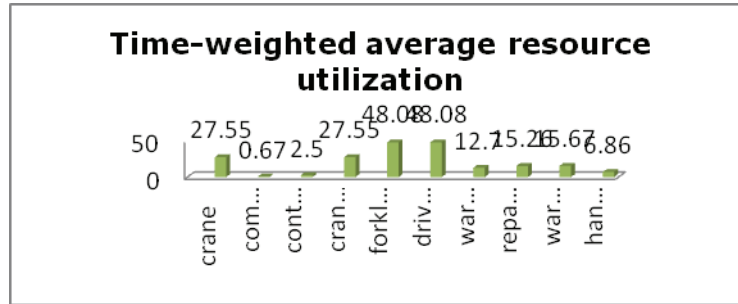


Figure 6: Resource utilization of TO-BE model

### COMPARATIVE ANALYSIS OF AS-IS AND TO-BE MODEL

From the data obtained by simulation of AS-IS and TO-BE models, it is concluded that TO-BE model shows better results compared to the AS-IS model. Organizational structure and division of the work activities in the AS-IS model causes longer transit time of containers in sectors (Table 1, Table 2) and higher money expenses necessary to perform work activities. TO-BE model has much more balanced resource utilization, than AS-IS (Figure 6, Figure 4). Manipulation cost of container handling in TO-BE model is 5,16 €, compared to the 6,35 € of AS-IS model. From the aforementioned it is concluded that the TO-BE model, is significantly more efficient and cost-effective for use in a real system compared to the AS-IS model.

### CONCLUSION

In this paper, the main research hypothesis was to examine the possibility of application of modeling and simulation of basic logistics processes in real logistics subjects, with the aim of improving the key functional parameters of particular logistics structure. To support this research two models were created, and they efficiently performed the identification of problem spots (AS-IS), and created more organized and cost-effective system for the functioning of the existing logistics system (TO-BE). Research results presented in this paper, shows that the use of modeling and simulation of business and logistics processes in container terminals, is fully justified and recommended. Further research should be focused to determine optimal level between amount of cost savings and investments implemented in TO-BE model. In that way optimal TO-BE scenarios could be created, depending of ratio of investmens vs. savings.

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# **POWER RESEARCH IN SUPPLY CHAINS: A REVIEW**

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## **1. INTRODUCTION**

The issue of power is an important area of study in social science. As stated by Cox (2001), power is at the centre of all business-to-business relationships. Despite the importance of power, it is still a factor which is usually overlooked in supply chain studies (Canieels and Gelderman, 2007). Based on this background, the purpose of this paper is firstly to discuss the concept of power and secondly evaluate several key approaches towards power measurement and power study in the context of supply chains (SC).

## **2. THE CONCEPT OF POWER DEBATE**

The root of power research resides in the field of political study. According to Sadan (1997), modern discourse about power dates back to the early 16th century when Machiavelli Niccolo published the book 'The Prince' in which the author regarded power as valuable asset and suggested several ways such as military actions and execution of political rivals that a prince can use to gain and maintain his power. More recently, Weber (1947) and Foucault (1980) contributed to the development of this concept and power research has been expanded from politics to a wide range of fields such as sociology, medicine, marketing and economics.

Despite of the popularity of power research, there seems to lack of a universally accepted concept of power (Gattorna, 1978). To some extent, this controversy can be seen in Table 1 which presents a summary of several definitions of power. Cox et al. (1985; 2002) employed the terms 'essentially contested' to justify the conceptual diversification of power from a theoretical perspective. To put this more specifically, Cox et al. (1985) believed that some concepts in social science such as art, socialism and democracy are invented for convenience in order to simplify complex social relationships and phenomena. Therefore, interpretation of the concept of power is debatable and may differ from man to man. Such concepts are evaluative as no single meaning can gain everyone's agreement due to the difference in value judgments or normative assumptions. In other words, concepts of power are 'essentially contested' because they are changeable to rational debate and unable to be formally verified.

Source	Power Definition
Blau (1964, p. 117)	Power is the ability of persons or groups to impose their will on others despite resistance through deterrence either in the forms of withholding regularly supplied rewards or in the form of punishment, inasmuch as the former as well as the latter constitute, in effect, a negative sanction.
Mokken and Stokman (1976, p. 37)	Power is the capacity of actors (persons groups or institutions) to fix or to change (completely or partly) a set of action alternatives or choice alternatives for other actors.
French and Raven (1959, p. 152)	The strength of power O/P in some system A is defined as the maximum potential ability of O to influence P in A.
Lukes (2005)	Power is the ability of one actor to affect the behavior of another actor in a manner contrary to the second actor's interest.

Table1: Selected definitions of power

Power has been studied in many fields including politics, sociology and economy etc. These disciplines have different or competing theoretical base and research traditions. Therefore, the concept and analysis of power has been approached from various theoretical directions with different assumptions. This makes the concept of power evaluative and incapable of formal and rational verification, thereby essentially contested. Due to this special feature, the development of a universally-accepted concept for power seems to be impossible and to some extent unnecessary. Even so, earlier appreciations about the concept of power are not without similarity. As can be seen in Table 1, a generally-accepted concept of power would be a social actor's ability to influence another social actor. This actor could be an individual, a group of individuals or an entity such as a firm.

### 3. APPROACHES TOWARDS POWER RESEARCH

The conceptual disagreement of power has not reduced researchers' interest in this topic. In the long history of power research, many approaches have been developed to study its relationship with regard to a range of factors such as performance, satisfaction and conflict. Among these approaches, a key issue is how power can be measured. This issue has formed the basis of power research.

#### 3.1 The classification of power measurement approaches--a broad perspective

One of the early works categorising different methods of power measurement was Frazier (1983) who claimed that there are primarily three approaches used in previous power research (prior 1983) to measure one company's influence on another. The first approach uses 'attributed influences measures' to measure power in which target firms assess the

extent that certain aspects of their decision making and/or behaviours are influenced by the source. Researchers adopting this approach include El-Ansary and Stem (1972), Etgar (1978), Lusch and Brown (1982) and Cronin et al. (1994). The second approach was developed by Etgar (1976) in his research focusing on power in the insurance industry. This approach employs an index of influence to reflect power through insurers' control over agents' premium volume, risk choice and representation of additional insurers. In addition, Frazier (1983) claimed that the third approach aims to measure power using hypothesized sources. In this approach, power sources and the level of dependence between actors are used to measure power. These two factors are believed to be critical to reflect one actors' ability to influence another party and are widely employed by power researchers to study power issues.

Zhuang and Zhou (2004) also presented a classification of major approaches measuring channel power. They are the dependence-power approach (El-Ansary, 1975; Frazier, 1983; Kale, 1986; Skinner et al., 1992; Gassenheimer and Ramsey, 1994; Provan and Gassenheimer, 1994; Canieels and Gelderman, 2007), power-bases approach (Hunt and Nevin, 1974; Lusch, 1976; Wilkinson, 1979; Frazier and Suaamers, 1986; Brown et al., 1995; Maloni and Benton, 2000; Bentona and Malonib, 2005) and ability-to-alter approach (Gaski and Nevin, 1985; Gaski, 1986, 1988).

It is noticeable that although the above power measurement approaches are labelled differently by Frazier (1983) and Zhuang and Zhou (2004), these two types of classification have similarities. Firstly, the 'ability-to-alter' approach seems to be homologous to the 'attributed influences measures' approach in a way that they are both developed on the basis of the essence of power concept to directly reflect 'the ability to influence'. The difference between these two lies in the dimension of measured power. Whereas the latter is accused of only measuring the exercised dimension of power, the former seems to also involve the unexercised dimension.

Wrong (1968) explained this issue from the perspective of defining power and argued that when power is regarded as the 'ability' to conduct alternation, it is a dispositional concept. He employed Gilbert Ryle's (1949, cited in Wrong, 1986, p.677) saying about 'knowing' to further explain this idea: *'To say that a person knows something, is not to say that he is at a particular moment in process of doing or undergoing anything, but that he is able to do certain things, when the need arises, or that he is prone to do and feel certain things in situations of certain sorts'*. Apparently, this statement also applies to the concept of power and 'having power' and 'exercising power' are fundamentally not the same thing. There might be circumstance that an entity has power over another but without using it (Cornin et al., 1994).

However, early power researchers such as EI-Ansary and Stern (1972), Estgar (1976) and Hunt and Nevin (1974) seem to neglect the difference between having and exercising power or attempted to measure power from the latter perspective while at the same time acknowledged that power is a dispositional concept (Gaski, 1984). In power research, this conceptual misuse seems to be connected with the attributed power measurement approach in which target firms assess the extent that certain aspects of their decision making and/or behaviours are influenced by the source. Accordingly, it seems that attributed measures only capture influencers' exercised or exercising ability to alter influencees' behaviours in specific areas whereas the unpractised ability of doing so is omitted.

Regardless of the debate concerning different dimensions of power, there is another similarity in above two classifications of power measurement approaches since Zhuang and Zhou's (2004) first two categories of power approaches can be regarded as the 'hypothesized sources' approach in Frazier's (1983) classification. In academia, this overlapping area which involves power-dependence and power base approach is used in a wide range of research to measure power. In light of this popularity, the following section provides a critical review of how those two approaches have been used to measure power.

### 3.2 Power sources as measurements of power

The examination of power issue on the basis of power bases has a long history. In the 1950s, Simon (1953) used the term 'influence base' to conceptualize the condition of exercising influence. The influence base stems from the value position of social actors and it includes authority and wealth etc. French and Raven (1959) categorized the source of social power into 5 groups. These five power sources and their description can be seen in Table 2.

Power source	Author's description (A refers to a person, whereas B refers to a person, a group or part of a group)
Reward power	Reward power is based on A's perception that B has the ability of mediate rewards for him.
Coercive power	Coercive power is based on A's perception that B has the ability to mediate punishments for him.
Legitimate power	Legitimate power is based on the perception by A that B has a legitimate right to prescribe behaviour for him.
Referent power	Referent power is based on A's identification with B.
Expert power	Expert power is based on the perception that A has some special knowledge or expertness.

Table 2: Five power sources

Source: adapted from French and Raven (1959)

Recognizing the contribution of French and Raven's (1959) work, the initial power source framework has been further improved by subsequent power researchers. However, there is a debate about whether and how this framework can be refined. Raven and Kruglanski (1970) has that in addition to the five power sources, there is another power source that has not been identified, namely informational power. This power source can be regarded as A's perception of B's ability to manipulate the informational environment in terms of providing new information and meaningfully interpreting information (Raven and Kruglanski, 1970; Lee, 2001). Moreover, several scholars have suggested that among the original five power bases, the legitimate power source can be further divided into two categories, namely legitimate power (the right of B is natural) and legal legitimate power (the right of B is based on legal agreement) (Kasulis and Spekman, 1980; Brown et al., 1983; Maloni and Benton, 2000).

Regardless of the debate about the spectrum of power sources, this research approach has formed the analytical and theoretical basis for many power studies. However, the power source approach seems to have a significant problem in terms of its applicability. The development of the original five social power sources by French and Raven (1959) is based on the influence of B on A (Table 2). Whereas A refers to a person, B as said by the authors can be 'either another person, a role, a norm, a group or a part of a group' (p.151). This means the development of five power bases does not consider the power relationship between groups which make its application to the context of SC questionable. Although the modification of the power source framework such as the division of legitimate power into two subgroups (legitimate and legal legitimate) seems to render the framework more suitable for inter-firm study, its applicability still needs to be carefully considered in a specific study. Concerns about the applicability of power source approaches in the context of SC also can be seen in EI-Ansary and Stem (1972) and EI-Ansary (1975).

In spite of this concern, extensive later research (Hunt and Nevin, 1974; Etgar, 1976; Wilkinson, 1981; Lush and Brown, 1982) have demonstrated that there exists a strong relationship between power sources and an entity's power in the SC context. For example, Hunt and Nevin (1974) have reported a strong relationship between coercive and non-coercive power source (reward, expertise, legitimacy and referent) available to the target and its power in a franchising channel. Such research on the one hand have justified the application of power source approach to the SC context, on the other hand highlighted the significance of this approach towards power measurement. However, on the basis of the examination of the findings of previous research, Brown et al. (1995) claimed that the correlation between power sources and an entity's power is uncertain. In other words,

although an entity may possess power sources, it may not be regarded by the target as powerful. The reason for this may lie in the application of influence and the situation of the SC climate.

### **3.3 Dependence as a measurement of power**

In addition to the power source approach, power-dependence is another significant approach towards power measurement. The idea that power stems from the relationship of resource dependency has a long tradition. The earliest systemic research about power-dependency was presented in 1960s by Emerson (1962) who claimed that power should be defined as influence and 'the power of actor A over actor B is the amount of resistance on the part of B which can be potentially overcome by A'. It equals the dependency of B upon A. In this power-dependence model, the determinants of dependence are motivational investment (goals and investment in goal mediation) and availability of alternatives (number of alternatives and switching cost) (EI-Ansary 1975). The far-reaching contributions of Emerson's (1962) study are at least two fold. Firstly, he argued that power was a property of the social relation rather than an attribute of the actors. Secondly, on the basis of the first argument, the author further claimed that the power pattern between different actors or organizations stemmed from their dependency relationship. To put this more specifically, the dependency of A on B would arise if the achievement of A's goals are facilitated by B's actions. Meanwhile, the relationship between A and B also involves a mutual dependency. In this relationship, both actors have the ability, to varying degree, to grant or deny the other's goals.

In the context of SCs, the dependence of one party on another is necessary and ubiquitous. As different actors in SCs are specialized in different functions such as raw material production, transportation and financing, they need to depend on each other to fulfil their own needs and deliver value to the final customer. While the measurement of power through dependence seems to be justifiable, in the first empirical power research, EI-Ansary and Stem (1972) tested Emerson's (1962) power-dependence model using data gathered from wholesalers and dealers in the heating and cooling industry in Ohio and found that there was an insignificant negative relationship between power and dependency. They attributed this abnormal finding to the lack of an established power structure in that dyadic relationship. Even so, it again raises concerns about whether the power measurement model (e.g. power sources and power-dependence) that were originally developed in a social setting can be unchangeably used in the context of SC.

In view of this consideration, early empirical evidence that supports the relationship between power and dependence, as well as between power and power sources (not based

on French and Raven's (1959) framework), can be found in Etgar (1976). In a dyadic relationship between insurers and insurance agents, both correlations turned out to be significant at the 5% level which provides support for these two power measurement approaches. However, insurers' power seems to be better explained by their power sources rather than the agents' dependence. According to Gaski (1984), an explanation for these findings (El-Ansary and Stern, 1972; Etgar, 1976) that question Emerson's (1962) power-dependence approach might be the conceptual inseparability of power sources and dependence. In other words, they can represent each other to some degree. For example, the ability of granting reward can partly reflect an entity's dependence on the influencer in order to achieve business success, on the other hand, motivational investment that covers a wide range of marketing mix such as site allocation and pricing can also reflect a channel member's power bases.

The homology of these two power measurement approaches is also recognized by Brown et al. (1983), Stern and El-Ansary's (1992), Berthon et al. (2003) and Zhuang and Zhou (2004). As an explanation, a focus is firstly given to the power-dependence approach in the context of SC. The underlying principle that supports this approach is that a firm depends on other SC member's resources to achieve its goals. In other words, the possessions of resources such as assets, information, raw material and know-how that are valued by a target company forms its dependence base to the holders and determines the resource-owner's ability to influence the target. Therefore, these valuable and scarce resources are also the bases of the holder's power (Stern and El-Ansary, 1992). Moreover, as these resources are diverse, they separately link to and combined to form the basis of French and Raven's (1959) five power bases. Thus, the power sources approach and power-dependence approach towards power measurement are highly connected and both variables (power sources and dependence) should be individually adequate to serve as indicators of power (Gaski, 1984). Alternatively, empirical evidence implies that power bases and dependence can also be complementary, rather than exclusive approaches towards power measurement. Specifically, Brown et al. (1983) found that whereas dependency and economic power bases (reward and punishment) were significantly related with the buyers' perception of their suppliers' power in domestic retailing industry, all six power bases (including information power base) had an indirect impact on power through their influence on dependence. A combination of these two power measurement approaches is thus proposed.

### **3.4 An 'objective' approach towards power study**

Power bases and dependency are two significant approaches towards power study. As



discussed earlier, these two approaches are conceptually inseparable which enables them to represent each other to some degree. Meanwhile, they both represent a subjective approach towards power study in a way that power are measured based on respondents' perception. However, Cox et al. (2002) claimed that this approach suffered from methodological problems since an actor's expressed view could not be taken as face value. Accordingly, they argued that power could also be researched from a subjective perspective. The basis for this division is whether interests or conflicts that are involved in a power relationship can be clearly recognised by social actors. Unlike the subjective approach, the objective power study is based on an outsider's point of view rather than an actor's expressed preference or feeling. This implies that supporters of this approach believe that power is not always correctly perceived by social actors because variables such as social norms can bias their perception.

In order to establish the theoretical base for the objective approach, Cox et al. (2002) firstly introduced the concept of rents and value. For the first factor, it refers to 'earnings of the firm's costs of production that are not eroded in the long run by new market entrants' (p. 6). From a resource-based point of view, rents will be acquired by those who control critical resources in the SCs. On the other hand, value in Cox et al.'s (2001a, 2002) works generally refers to the revenues that are allocated to different actors in a series of exchange relationships in SCs. On the basis of this view, the acquiring of rents and value are closely related and their distribution to different firms can map power relationships in SCs. In other words, a firm's acquiring of rents and value tends to be directly proportional to its power. In addition to the above two factors, Cox et al. (2002) claimed that a power typology for exchange relationships should also include variables including: information, scarcity and utility. Whereas scarcity and utility shapes the dependency relationship among firms, the first variable has major impact on the formation and maintenance of an isolating mechanism that can help a firm to gain and keep power.

On the basis of this theoretical framework, Cox et al. (2002) claimed that there were four possible power relationships between buyer (A) and supplier (B):  $A=B$  (buyer-supplier interdependence),  $A>B$  (the existence of powerful buyer and less powerful supplier),  $A<B$  (the existence of powerful supplier and power-disadvantaged buyer) and  $A \neq B$  (buyer-supplier independence). The objective approach towards power research has several advantages. Firstly, it has greatly contributed to the identification of power regimes within SCs and establishes a standardized power measurement approach to deal with this issue. Secondly, it suggests an extension of the scope of power research from dyadic relationship to multi-dimensional relationships in SC. As claimed by Cox (2004), for a firm to succeed in power-affected SCs, it needs to have the power to appropriate value from its

suppliers or its customers or, in the best situation, both. Moreover, it is also worth knowing how power functions among a number of dyadic exchange relationships in the SC. In comparison to the subjective approach, which mainly focuses on power analysis in dyadic relationship, the objective approach offers a practical way to solve these two issues.

Accordingly, the objective approach has been used by Cox (2004), Cox et al. (2001 a, b; 2002) to develop various power regimes in SCs and to investigate power relationships in many industrial sectors such as advertising and tourism. Even so, its application is still limited. This may be because research on power in SCs is philosophically dominated by positivism while power in Cox et al.'s (2002) objective approach is difficult to measure statistically. Moreover, it does not seem to be convincing to research power relationships among social actors without knowing their own view about their power positions.

#### **4. CONCLUSION**

In conclusion, power has long been recognized as an important relationship in social systems. However, the concept is debatable in academia because it is essentially contested. Due to this special feature, the development of a universally-accepted concept for power seems to be impossible and to some extent unnecessary. In this paper, several approaches towards power measurement and research have been evaluated. The question concerning whether power should be studied objectively or subjectively generates two significant approaches towards power study. To study power subjectively, the key issue is to figure out how power can be measured. In literature, power bases and power-dependence are two important approaches that have been well developed in order to solve this problem. On the other hand, the objective approach toward power attempts to study it from an outsider's point of view rather than an actor's expressed preference or feeling. This approach has contributed to the identification of power regimes within SCs and suggested an extension of the scope of power research from dyadic relationships to multi-dimensional relationships in SCs. All in all, it seems that each approach has its advantages and disadvantages. However, they are not exclusive and it is possible to combine several approaches in order to better explain power in SCs.

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# IMPACTS OF RESOURCE CONFIGURATIONS ON MOTIVES FOR REDUCING CO<sub>2</sub> EMISSIONS IN FREIGHT TRANSPORTATION

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## ABSTRACT

The aim of this study is to increase the understanding for how different resource configurations impact on CO<sub>2</sub> reductions in freight transportation. The results show significant differences between the motives to reduce CO<sub>2</sub> emissions between large companies and SMEs, and LSPs and other industries. Whether the logistics structure is deemed as “environmentally friendly” has only a minor impact on motives for reducing transportation emissions, and the results did not show any differences with regard to modal choice. Implications of the results are presented in the paper.

## INTRODUCTION

Transportation emissions have been in the spotlight in policy (Doherty *et al.*, 2010) and in practice (e.g. GHG Protocol, 2011) in the past years. Research on transportation emissions has focused on emission calculations in last mile deliveries (and delivery failures, McLeod *et al.*, 2006), comparisons of kerbside vs. home delivery schemes in retailing (Edwards *et al.*, 2011), on the drivers of emissions (McKinnon and Piecyk, 2009) as well as on the sheer problem of their actual calculation (McKinnon, 2010; Litman, 2011). Transportation emissions have been assessed on various levels: the product level (McKinnon, 2010), consignment level (Doherty *et al.*, 2010), company and supply chain levels (Piecyk, 2010) but also in terms of their interlinkage with infrastructure decisions (Harris *et al.*, 2011) and economic analyses (Litman, 2011).

Transport policy and the link to infrastructure decisions highlight the importance of transportation emissions for various stakeholders. Governments and supragovernmental organisations (such as the World Economic Forum) exert pressure on companies to reduce transportation emissions. At the same time, consumers have also expressed an interest in the emissions a product causes – an example of which is the discussion on “food miles” and the local organic food movements (Garnett, 2010). Also business customers have started to consider environmental aspects in the selection of third party logistics providers (Meixell and Norbis, 2008, Wolf and Seuring, 2010).

However, little is understood why companies choose to incorporate environmental considerations in transportation. Wolf and Seuring (2010) list customer demand, laws, and environmental product development as the three main reasons to reduce transportation emissions. ElTayeb *et al.* (2010) consider four drivers: regulations, customer pressure, social responsibility, and expected business benefits. From the perspective of competitiveness, Porter and van der Linde (1995) see two main motives for greening: cost efficiencies through resource reductions following “green and lean” thinking, and innovations. They argue against the role of regulators in driving greening. Differences in company motives can be argued for through differences in resource configurations across industries, e.g. due to varying degrees of outsourcing of transportation services. This paper aims to increase the understanding for how different resource configurations impact on motives for CO<sub>2</sub> reductions in freight transportation.

The paper is structured as follows: First we review literature related to CO<sub>2</sub> emissions in freight transport, with a focus on industrial differences in resource configurations. Based on these, hypotheses are developed and tested in a large industry survey of freight transport-intensive industries in Sweden. We conclude with a discussion of findings, conclusions and implications for transport policy.

### **The diverse resource configurations of transport-driven industries**

According to Sarkis *et al.* (2011), the first main reason to consider industrial pollution stems from a policy perspective, in fact wanting to tax pollution. Yet, probably more interesting than the external pressure view on pollution in transportation is the question which other reasons industry may have to reduce pollution – which in freight transportation to date focuses to a large extent on CO<sub>2</sub> emissions. To answer this question, the resource based view (RBV) emphasises the link between the use of (heterogeneous) resources to achieve competitive advantage (Carter and Rogers, 2008; Barney *et al.*, 2011). Within RBV, the natural RBV has been most focused on also including natural resources alongside other assets, skills and capabilities in the list of resources (Hart and Dowell, 2011) and hence widens the view towards pollution as well.

The heterogeneity of resources and resource configurations can also be extended to logistics, as shown by Kovács and Tatham (2009) for military and humanitarian logistics. A main difference is between the motives for manufacturing companies vs. those for logistics service providers (LSPs) to reduce transportation emissions. For LSPs transportation is the core business, while it is more peripheral to most freight owners with in-house transportation. Therefore, the motives for addressing transportation emissions may vary. LSPs and companies that control logistics operations in-house are expected to pursue a

lean equals green approach to transportation emissions when it comes to fuel efficiencies, economies of scale from bundling transportation and from filling back-hauls. Companies that outsource decisions for transport operations have less prioritisation on these issues. The logistics resource configuration of a firm could be defined by the logistics structure (Aronsson and Huge Brodin, 2006). To minimise the environmental impacts, the logistics structure should have few movements, short transport distances with high amount of direct shipping and high utilisation of transports (Wu and Dunn, 1995). Thus, the environmental impacts of a logistics structure are affected by the location of facilities, transport routes and mode of transport used. Another differentiating factor is company size, as regulations, also related to transport policy, tend to differ between small and medium-sized companies (SMEs) and larger ones, typically introducing stronger requirements for large companies. Based on this introduction, we hypothesise that:

**H1.** Large companies have significantly stronger motives for reducing transportation emissions than SMEs do.

**H2.** LSPs have significantly stronger motives for reducing transportation emissions than freight owners do.

**H3.** Companies with in-house control over transport operations have significantly stronger motives for reducing transportation emissions than companies with outsourced decisions.

**H4.** Companies with an “environmentally friendly” logistics structure (few movements, short transport distances with high amount of direct shipping and high utilisation of transports) have significantly stronger motives for reducing transportation emissions than companies with less environmentally friendly logistics structures do.

### **Survey Instrument**

The hypotheses were investigated in a survey of freight transport-intensive industries in Sweden focused on the disposition of these industries to reduce CO<sub>2</sub> emissions. This section explains the development of the survey instrument, the data collection and how the data were analysed. The motives included in the survey were developed in a literature review, which is summarised in the introduction. The motives were investigated on a five-point Likert scale ranging from *very low* to *very high*. In-house vs. outsourced operations were measured in two dimensions, i.e. whether the logistics planning (internal/external operator) and the execution of transport decisions (internal/external operator) were outsourced or not. The logistics structure was measured through type of distribution chain in the responding company (direct delivery/via warehouses), main route type (fixed/unique routes), and the share of the freight using different means of transportation (money spent on road, rail, sea and air).



Our survey was pre-tested as suggested by Flynn *et al.* (1990). To gain feedback about the structure and clarity of the survey, it was pre-tested on eight logistics academics. Based on their feedback, the survey was modified: a few questions were rephrased for clarity or deleted and then discussed with the respondents. The revised survey was then tested on five industry representatives. This resulted in minor modifications: the survey was slightly restructured and some questions were rephrased.

### **Sampling strategy**

The survey was directed at companies in freight transport-intensive industries in Sweden (Table I). Sweden was selected because the authors have in-depth knowledge about trade and industry in this country and because Sweden is in the forefront of environmental logistics illustrated by high rankings on logistics performance (the global LPI ranking, World Bank, 2012) and environmental performance (environmental performers globally, Yale, 2012).

To get a representative sample of companies, the nine most freight transportation-intensive industries in Sweden were selected. This resulted in a total population of 1095 companies with >50 employees. A stratified sample in two dimensions was used to avoid an imbalance among the groups. First, the companies were divided into four groups: very small, small, medium-sized, and large companies. All large companies (i.e. the 142 companies with 500 or more employees) were included in the sample. Then, three equally large groups of companies with 50-99, 100-199 and 200-499 employees were systematically selected. In total, 427 companies were included in the sample.

To identify key informants at each firm, we were guided by the recommendations provided by Bagozzi *et al.* (1991): we contacted switchboards and enquired about the most suitable respondent regarding the current and future logistics decision-making procedures, logistics structure and freight transport solutions of the companies. We called all 427 companies, explained the purpose of the survey and particularly the criteria for the respondents. The appropriate respondents corresponded mostly with the corporate head of logistics (hereafter referred to as "logistics managers"), but in a few cases the company deemed another respondent to be more suitable.

### **Data collection**

The data collection took place in Nov-Dec 2010. The logistics managers of the selected firms were e-mailed an explanatory cover letter accompanied by a link to a web-based survey. The cover letter explained the research, asked for their help to complete the

survey, promised a prompt copy of the results of the study to encourage participation (as in Frohlich, 2002), and emphasised confidentiality. Reminders were sent to non-respondents weekly for 3 weeks after the first e-mail. Follow-up telephone calls three weeks after the initial e-mail were made to obtain additional responses. The 172 responses received represent a response rate of 40.3%, evenly distributed between the different dimensions. Fourteen responses were removed due to incomplete data. Table I provides frequency distributions of number of employees and industry. Several non-respondents were contacted by phone in the follow-up calls. The reason most often cited for non-response was lack of time, followed by company policy. To check for non-response bias, respondents and non-respondents were compared on characteristics known *a priori* (Wagner and Kemmerling, 2010), and by comparing early responses to late responses. No statistically significant differences or trends were found, which indicates the absence of non-response bias.

Industry/No. of employees	50-99	100-199	200-499	> 499	Total
Agriculture/Forestry	1	7	2	1	11
Chemical	6	4	4	5	19
Food and drinks	10	7	5	8	30
Manufacturing		5	6	8	19
Manufacturing other			4	5	9
Ore/Metal	2	6	10	12	30
Pulp, paper and paper articles		3	5	7	15
Wholesale trade	7	1	1	13	22
Logistics and transport providers	1	8	6	2	17
<b>Total</b>	<b>27</b>	<b>41</b>	<b>43</b>	<b>61</b>	<b>172</b>

Table 1. Frequency distributions of number of employees and industry

### Discussion of findings

The entire sample was analysed as the hypotheses were tested using t-tests. The analysis examined the impacts of company size, the different elements of LSPs vs. freight owners, in-house or outsourced control over transport operations, and logistics structure on motives for reducing CO<sub>2</sub> emissions for all companies. Table II summarises the hypothesis tests.

H1: To test H1, we conducted t-tests for each motive. Large companies were defined as equal to or above 400 employees and SMEs below this figure. The analysis shows that four *motives* are significantly more important for large companies than for SMEs: *long-term competitiveness*, *marketing advantage*, *environmental employer*, and *showing social*

*responsibility*. The analysis does not show any significant difference in the motive to gain *company profitability* for large and SMEs. We also tested the motives for reducing CO<sub>2</sub> emissions from freight transport. The analysis shows that *customer requirements* and *owner requirements* are significantly more important for large companies than for SMEs. However, contrary to expectations, we could not find any support for the hypothesis that *authority requirements* are more important for larger companies.

	H1	H2	H3a	H3b	H4a	H4b	H4c <sub>1</sub>	H4c <sub>2</sub>	H4c <sub>3</sub>	H4c <sub>4</sub>
	Large companies vs. SMEs	LSP vs. Freight owner	In-house vs. Outsourcing		Direct delivery vs. Warehouse	Fixed route vs. Unique route	Mode of transport			
	Large companies: ≥ 400 employees		Own planning vs. External planning	Own execution vs. External execution			Share road	Share rail	Share air	Share sea
Motive	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Long-term Competitiveness	.007**	.006**	0.922	.760	0.012*	0.103	.848	.744	.097	0.582
Marketing Advantage	.009**	.001**	0.257	.831	0.112	0.450	.178	.769	.447	0.274
Company Profitability	.676	.000**	0.784	.136	0.057	0.299	.589	.944	.376	0.095
Environmental Employer	.004**	.121	0.410	.705	0.198	0.359	.968	.881	.115	0.947
Social Responsibility	.005**	.102	0.411	.659	0.028*	0.673	.965	.231	.302	0.702
Customer Requirements	.037*	.000**	0.503	.748	0.277	0.211	.759	.375	.140	0.336
Authority Requirements	.400	.934	0.368	.349	0.164	0.409	.725	.685	.693	0.778
Owner Requirements	.002**	.013*	0.465	.110	0.455	0.681	.067	.753	.298	0.664

\*\* Significantly true with 99% confidence

\* Significantly true with 95% confidence

H4c<sub>1</sub> Tested for companies that spend ≥90% of their transport costs on road transport (n=58) against the other companies (n=93)

H4c<sub>2-4</sub> Tested for companies that spend ≥10% of their transport costs on rail/air/sea transport (n=42/32/78) against the other companies (n=109/119/73)

Table 2. Results of two-sample t-tests for impacts of resource configurations on motives for greening transports

H2: Results from the t-tests (see Table II) indeed indicate that some motives for reducing transportation emissions are significantly higher for LSPs. These are long-term competitiveness, marketing advantage, being an environmental employer, social responsibility, company profitability, as well as customer and owner requirements. However, requirements from authorities do not seem to follow the same pattern and the difference between industries is not significant here.

H3: To test this hypothesis, two dimensions of transport decision-making were tested. We tested whether the freight transport planning process was conducted in-house or outsourced (H3a). We also tested whether the freight transport execution was conducted in-house or outsourced (H3b). However, none of the tests revealed significant correlations. The hypothesis was not supported. The results indicate that from a motivational perspective for CO<sub>2</sub> reduction it does not matter whether the transport operations are the core business activity (as for LSPs) or not (as for freight owners with internal planning and execution of transport).

H4: To test this hypothesis, three dimensions of logistics structure related to freight transport were analysed. These dimensions are discussed by Wu and Dunn (1994) as they describe the options that logistics managers can choose from for environmentally responsible practices. We tested main distribution structure (direct delivery or via warehouses), main route type (fixed or unique), and mode of transport used (road, rail, air, and sea):

H4<sub>a</sub> (direct delivery/via warehouses): According to the results of our t-tests, companies distributing their items via warehouses have significantly higher motives related to long-term competitiveness and social responsibility to reduce transportation emissions.

H4<sub>b</sub> (fixed vs. unique route): No significant correlations with any motives to reduce transportation emissions.

H4<sub>c1</sub> (share road), H4<sub>c2</sub> (share rail), H4<sub>c3</sub> (share air), H4<sub>c4</sub> (share sea): None of these have any significant correlations with any motives to reduce transportation emissions.

In essence, the analysis reveals only minor support for this hypothesis, with the exception that companies using warehouses / cross-docking points for their distribution seek a reduction in CO<sub>2</sub> emissions in order to obtain long-term competitiveness and show social responsibility, and this with a significant difference to companies that mainly employ direct deliveries. We can only speculate that the investment into the use of warehouses and cross-docking points is a long-term one, and is therefore also related to a reduction of transportation emissions from the perspective of long-term competitiveness. Having a distribution structure with warehouses or cross-docking points may also be more complex

than direct delivery meaning that the number of alternatives for distribution is greater. Therefore, the potential to find more CO<sub>2</sub>-efficient and cost-efficient alternatives in the long term may seem greater as well. Furthermore, emissions from long-distance transport due to global supply chains have been highlighted in media and by NGOs in Europe recently. Companies having warehouses or cross-docking points are likely to have longer supply chains than those with direct delivery. Changes in these structures to reduce transport emissions may be an approach to meet such external demands and show social responsibility.

Most companies in Sweden use road transport to a great extent. To test the influence of mode of transport on motives to reduce transportation emissions, we used the amount of money spent on different modes of transport. We expected different modes of transportation to relate differently to the reduction of CO<sub>2</sub> emissions, especially as the European Union is promoting e.g. rail transport as a "greener" option. Thus we carried out four tests: share of road  $\geq$  90%, share of rail  $\geq$  10%, share of air  $\geq$  10%, and share of sea  $\geq$  10% - but interestingly, none of these revealed any significant differences. From a transport policy perspective, these results indicate that the promotion of rail transportation has not been embraced by Swedish companies. It is though not clear from the results whether this is due to a policy failure or problems with rail freight transport.

### **Conclusions and implications for transport policy**

The aim of this study was to increase the understanding for how different resource configurations impact on CO<sub>2</sub> reductions in freight transportation. Our results show that there are indeed significant differences between the motives to reduce transportation emissions between large companies and SMEs. Contrary to expectations, however, none of these directly relate to transport policy. The motives for large companies to reduce transportation emissions related to long-term competitiveness, marketing advantage, environmental employer, and showing social responsibility – all of which are aspects of company strategy, branding, and internal motivational aspects overall. The reduction of transportation emissions has become a differentiating factor on the market, a marketing tool, and a way to attract and retain good employees rather than a matter of compliance. Having been exposed to an EU transport policy promoting greening for a long period of time, large companies have seemingly internalised this policy and have started to exploit greening for their own marketing advantage.

Authorities, and hence, transport policy, are also not the significant motives for LSPs towards greening – even though LSPs are more motivated than other industries to reduce transportation emissions, perhaps as this relates to their core competence. Again, we

conclude that LSPs have internalised and embraced greening. That they see the reduction of transportation emissions as important from so many different perspectives only goes to show that the discussion about CO<sub>2</sub> emissions has become an everyday matter in this industry. At the same time, not being the core competence of other industries, this discussion is obviously still less important to others. Transport policy would therefore need to focus more on the buyers of logistics services rather than on LSPs directly in order to increase the motivation of industries and effectively achieve an overall reduction of transportation emissions. At the same time, puzzlingly, we did not find any significant differences between the motivation of companies who control and those who do not control their distribution directly. In other words, there is no difference between industries that use and those who do not use the services of LSPs. An implication for transport policy can be that the same attention should be paid to transportation managed in-house as has been paid until now to LSPs.

Our results showed that whether the logistics structure is deemed as “environmentally friendly” as defined in current literature has only a minor impact on motives for reducing transportation emissions. This indicates that transportation emissions are only considered to a little extent when companies design their logistics structure. To increase the importance make companies change to more “environmentally friendly” logistics structures, transport policy should focus on increasing motives supporting this issue. Future research should address how these motives can be increased.

We did not find significant differences with regard to modal choice can be either interpreted as a failure of transport policy, or alternatively for rail, stem from problems with rail transportation in Sweden. Further research is needed to investigate the cause of rail transportation not being linked to a motive of reducing transportation emissions.

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# **TRANSPORT COLLABORATION: A FRAMEWORK TO INVESTIGATE THE KEY OPERATING CRITERIA**

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## **ABSTRACT**

Building transport coalitions require a good combination of accommodating operating criteria. In this research, a content analysis framework integrated with case study approach is proposed to determine the key operating criteria for building a transport coalition. This paper gives only the preliminary findings for the key operating criteria. The next research is going to use these and select more relevant ones in order to create a strategic alignment framework.

## **INTRODUCTION**

Companies are often faced with fundamental decisions while reconfiguring their transport strategies and streamlining transport management processes. Among these decisions are: whether to keep transport in-house or the use of outsourcing or *transport collaboration* in order to share the synergy benefits with other companies/organizations from the same or different supply chains (Kayikci and Zsifkovits, 2012a). Transport collaboration is a new shipper-carrier partnership strategy. The main objective of transport collaboration is to improve the operating performance of all entities involved in the relationship by eliminating the cost of transport inefficiencies due to high empty running, idle waiting time, less-than-truck-load (vehicle fill) across transport chain through collaboration. Transport collaboration can be considered as a strategic asset for optimizing the supply chain and improving the competitiveness of companies (Kayikci and Zsifkovits, 2012b). In transport industry, collaboration occurs when two or more companies (transport users and/or transport service providers) from the same or different line of business form a coalition and exchange information and resources in order to meet imposed performance requirements. They could obtain greater benefits from their collaboration than they cannot generate individually. This new innovative form of business existence is based on the concept that by clustering specific transport and logistics activities and consolidating different supply chains, significant economies of scale can be achieved in terms of efficiency (with respect to cost), effectiveness (with respect to customer service) and environmental sustainability (with respect to being "green" in their carbon footprint) (Bartolacci *et al.*, 2012). In the building of transport coalition, the transport collaboration strategies can vary with the form

of collaboration as well as the level of integration between distinct organizations (Kayikci and Zsifkovits, 2012b). The form of collaboration is driven in three planes, respectively: vertical collaboration (shipper and its carriers in the same supply chain), horizontal collaboration (a number of shippers or carriers in different supply chains) and lateral collaboration (combining of vertical and horizontal collaboration and composed of a number of shippers and carriers in different supply chains) (Simatupang and Stridharan, 2002; Barratt, 2004; Mason et al., 2007). This study focuses on the heterarchical<sup>1</sup> transport collaboration strategy where the both transport users and the transport service providers join into the collaborative actions laterally. Today's transport collaboration models are powered by advanced software systems and the Internet, which allow companies to expand collaborative transport networks on a large scale. The developments in Information and Communication Technologies (ICTs) are creating a new operational landscape for transport collaboration systems (Mason and Lalwani, 2006); in this respect ICTs are the main enabler of this collaboration. In effect, companies are forming web-based, as well as more traditional partnerships, to reduce the transport and inventory costs while raising the bar on customer service. However, building a coalition is not always easy (Audy et.al, 2007) and might include having to deal with disparate problems. Transport managers often ask the question: *why do some transport coalitions can succeed to pursue a long-term relationship and the others fail?* The answer to this question depends on the multitude of criteria and a set of interactive relationships between them which can constitute the transport collaboration structure. In this respect, the purpose of this research is to identify the key operating criteria for establishment of transport coalition by proposing a content analysis framework. The framework is based on *literature review* inclusive technical papers, white papers, conference papers and electronic resources. This framework is designed to explore and support the long-term successful transport collaboration for the participants. In this research, we investigated 72 most relevant key criteria for transport collaboration structure. These criteria are aligned with pre-defined contents by using three case studies. This paper assumed an inter-organizational integration for all coalition participants. It aims to provide valuable insights for coalition initiatives in heterarchical transport network. In addition, these initial criteria are going to be used as a toolkit for further research papers in order to develop a strategic alignment framework.

## **METHODOLOGY**

The proposed methodology is based on the content analysis method and the case study interviews. Content analysis is a research approach used to make objective and systematic

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<sup>1</sup>Heterarchical collaboration differs from hierarchical ones in terms of the nature of control within the coalition where the leadership is shared between the transport users and the transport providers; therefore there is no hierarchy in the coalition and all participants have equal rights and responsibilities.

inferences on theoretically relevant messages. Content analysis is based on three stages: (1) sources for the literature review and case studies, (2) content classification scheme, (3) classification procedures.

### **(1) Sources for the literature review and case studies**

Collaborative actions between supply chain partners, competitors and non-competitors in transport management are still in vogue (Mason and Lalwani, 2006); only a few companies have truly capitalized on the potential of collaborative business models. Collaboration has been studied in different contexts in the available literature (Barratt, 2004). However, only a few studies which have focused on collaboration in the context of transport (Mason et al., 2007; Cruijssen et al., 2007; Naesens et al., 2007; Audy et al., 2007; Graham, 2011). Prominent examples can be found in the automotive industry (Graham, 2011), retail industry (Mason et al., 2007), catering sector (Cruijssen et al., 2007), motor carrier industry (Fugate et al., 2009) and wood/forest industry (Audy et al., 2007). Similarly, some researchers have pointed out that limited literature exists on the strategic aspect of collaboration in transport and logistics and that this existing research seems to focus, for the most part, on descriptive aspects (Cruijssen et al., 2007; Naesens et al., 2007).

Research Strategy	Description
Used key words:	"transport collaboration", "collaborative logistics", "lateral collaboration", "collaborative transportation management", "collaborative communities", "collaborative transportation networks", "logistics collaboration", "carrier collaboration", "shipper collaboration", "horizontal collaboration", "information and communication technology in transport and logistics", "electronic logistics marketplaces"
Search engines:	www.google.com, www.business.com, www.yahoo.com
Scientific online literature databases:	ABI/Inform ProQuest ( <a href="http://search.proquest.com/">http://search.proquest.com/</a> ), EBSCO ( <a href="http://search.ebscohost.com/">http://search.ebscohost.com/</a> ), ACM Library ( <a href="http://dl.acm.org/">http://dl.acm.org/</a> ), Emerald ( <a href="http://www.emeraldinsight.com/">http://www.emeraldinsight.com/</a> ), Springer ( <a href="http://link.springer.com">http://link.springer.com</a> )
Additional research databases	Aberdeen Group ( <a href="http://www.aberdeen.com/">http://www.aberdeen.com/</a> ), AMR Research ( <a href="http://www.amrresearch.com/practices/scs.asp">http://www.amrresearch.com/practices/scs.asp</a> ), Deloitte Research ( <a href="http://www.deloitte.com">http://www.deloitte.com</a> ), Forrester ( <a href="http://www.forrester.com/">http://www.forrester.com/</a> ), Transport database ( <a href="http://ovidsp.tx.ovid.com/">http://ovidsp.tx.ovid.com/</a> )
Internet portals	Numerous portals: dissertation online ( <a href="http://www.educat.hu-berlin.de/diss_online/biblio.html">http://www.educat.hu-berlin.de/diss_online/biblio.html</a> ), electronic markets, information and communication technology in transport and logistics, DBLP Computer Science Bibliography ( <a href="http://dblp.uni-trier.de/">http://dblp.uni-trier.de/</a> ), eyefortransport ( <a href="http://www.eft.com/">http://www.eft.com/</a> ) etc.

Table 1: Literature review strategy

The trend towards increased collaboration is visible in two respects (Kayikci and Zsifkovits,

2012b): Firstly large companies have started to focus on core competencies and have subcontracted certain parts of processes including transport processes. Secondly a tighter integration involves not only supply chain partners, but also direct competitors who can bring crucial benefits instead of just a traditional market relationship. In addition the goal of transport collaboration is based on the idea creating a transparent and visible demand pattern that affects the entire chain to reach synchronized supply. In this respect, a literature review strategy is adopted in order to review the most relevant literature (see Table 1). As a result of the literature search, 40 most relevant research articles (incl. journal paper, book chapter, online resources etc.) are compiled in a list as seen in Table 2. Additionally, the case study approach is adopted into the content analysis, as case study allows researchers to retain the holistic and meaningful characteristics of real-life events (Yin, 2003), such as organizational and managerial processes, for example. In fact, case studies seem to be the preferred strategy when "how or "why" questions are being posed, when the researcher has little control over the events, and when the focus is on a contemporary phenomenon within some real-life context. Three real world coalitions are mentioned as case studies in this study. The first real-case refers to a coalition (Coalition A) between two medium size companies from the tire industry which decided to manage their outbound transport operations by using same carrier company and common distribution center (DC)/storage area. The second example shows a large coalition (Coalition B) between six automotive companies which act conjointly for outbound transport operations by using ten carrier companies. The third coalition (Coalition C) is composed of three small size companies from fast moving consumer goods (FMCG) industry which use same carrier company for transport operations. The details of real case studies can be seen in Table 3. All case studies are performed on the multi-echelon heterarchical transport network. All coalitions aim at centralizing transport management and sharing transport capacities in order to cut transport cost and to enhance asset utilization. Every coalition's partners serve the same market area and face multiple LTL shipments.

#	References	#	References	#	References
1	Audy et al., 2007	13	Cruijssen et al., 2007	28	Naesens et al., 2007
2	Audy et al., 2010	14	Esper and Williams, 2003	29	Perego et al., 2011
3	Azevedo et al., 2008	15	Esper et al., 2010	30	Pokharel, 2005
4	Balocco et al., 2010	16	Evangelista and Kilpala, 2007	31	Pralhad and Ramaswamy, 2001
5	Barratt, 2004	17	Evangelista and Sweeney, 2006		
6	Bhimani, 2007	18	Fugate et al., 2009	32	Ritter et al., 2007
7	Camarinha-Matos and Afsarmanesh, 2005	19	Golicic and Mentzer, 2006	33	Simatupang and Stridharan, 2002
		20	Graham, 2011		
8	Camarinha-Matos et al.,	21	Gustavsson, 2008	34	Soosay, 2008

	2009	22	Hidalgo and Lopez 2009	35	Stank and Goldsby, 2000
9	Chan and Zhang, 2011	23	Hilty et al., 2006	36	Tan et al., 2009
10	Childerhouse et al., 2003	24	Kale et al., 2007	37	Toh, et al., 2009
11	Christiaanse, 2005	25	Marchet et al., 2009	38	Verstrepen et al., 2009
12	Coronado Mondragon et al., 2009	26	Mason et al., 2007	39	Visser, 2010
		27	Mentzer, et al., 2000	40	Wang et al., 2007

Table 2: References according to alphabetical order.

Coalition	Integration Initiators	Size	Sector	Categorization	Integration	Integration Area
A	2 TUs + 1 TSP	Medium	Automotive supplier industry	International	Tactical	Resource (truck & warehouse) pooling, joint-route planning
B	6 TUs + 10 TSPs	Large	Automotive industry	International	Operational	Outbound transport operations, joint-route planning, resource (truck) pooling
C	3 TUs + 2 TSPs	Small	FMCG	National	Strategic	Joint-investment in new single regional DC, joint planning and execution

Table 3: Definitions of case study

## (2)Content classification scheme

The second part is the definition of contents. The proposed framework is composed of the six major contents: drivers, facilitators, components, decision, business processes and outcomes. These contents are adopted from the relationship models of Stank and Traichal (1998) and Lambert et al. (1999). The contents for drivers, facilitators, components, decision and outcomes are from Stank and Traichal (1998) and the contents for components, business processes refer the model of Lambert et al. (1999). Figure1 depicts these contents and draws the outline of their relationships where the dashed lines indicate the “feedback” from collaboration drivers, facilitators and components. Here, these contents are searched in depth in the literature with respect to the relationships of multiple organizations (multi-lateral) in a heterarchical transport network that mainly includes three integration initiators: transport users (shippers and receivers), transport service providers (carriers and third-party logistics providers) and/or technology provider (platform provider) (Kayikci and Zsifkovits, 2012b). That setup shown resembles network-based solutions (Wang et al., 2007). Technology provider represents the neutral part and plays a coordination role to provide the information exchange within other units (Audy et al., 2007); therefore it has no influence in the building of coalition.

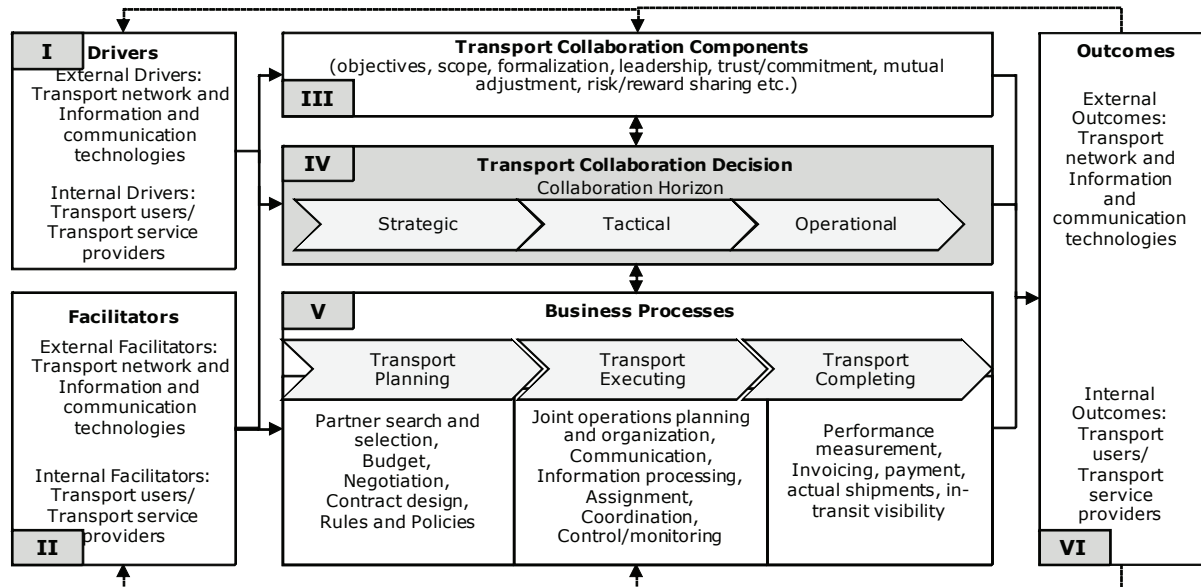


Figure 1: The content analysis framework for transport coalition

The definitions of contents are as follows:

*I-Drivers:* Drives for all coalition partners indicate the potential significant benefits through collaboration. These benefits are generally to gain market advantages, to reduce inefficiencies (i.e. empty run, asset utilization).

*II-Facilitators:* Facilitators support the development business processes and the growth of relationship. Heterarchical transport collaboration offers a high democracy in the coalition where all coalition units have equal right and they collaborate for the sake of win-win outcomes.

*III-Components:* Drivers and Facilitators can only establish the potential for transport collaboration. These alone are not enough to manage successful collaboration. It should be also determined how coalition should operate. The criteria like objectives, scope, the level of trust/commitment, mutual adjustment, control rights etc. should be determined appropriately.

*IV-Decision:* This part refers the decision on the level of collaborative integration. Transport collaboration differs according to their *level of collaborative integration* from a very superficial "arm's length relationship" to a highly integrated "strategic relationship" among coalition partners (Lambert et al. 1999; Kayikci and Zsifkovits, 2012b). The *arm's length* relationship is not considered to be actual collaboration mostly in literature since there is no stable joint commitment between coalition units; this means there is "*no integration*". The level of integration lies generally on the density of information, the critical mass of the network and the real-time nature of information shared (Christiaanse, 2005). The higher the level of integration, the longer is the life period of transport coalition. Therefore the long-term goal of collaboration should be "full-integration" for all participants. Figure 2 depicts the growth path of transport collaboration where three steps determine the level of

collaborative integration. The first step for *limited collaboration* refers the operation based integration which involves the overlapping of functional areas between mutually recognized partners. Operational decisions up to 6 months are taken on a limited basis for a short-term horizon with specific needs and resources. The second step for *integrated collaboration* refers the coordination based integration in which coalition partners integrate parts of their planning and coordination activities within a time span between 0.5 to 5 years; they make tactical decision, which would not require high investment and risk, therefore a long-term partnership is not the goal in this step. In short, these two steps can depict the “*partly integration*” of coalition units. The last step for *strategic partnering* refers the strategy based integration, which represents the “*full-integration*” that includes a convergence of cost, process and technology. Each partner considers the other as an extension of itself considering a long-term engagement with no ending-date for the respective partnerships.

*V-Business Processes:* The inter-organizational interactions in a transport coalition are described in a set of generic business processes that covers transport planning, executing and completing (Kayikci and Zsifkovits, 2012a) which are based on the strategic, tactical and operational levels of collaboration. Coalition members should come into consensus to align the business processes. Here it is important to clarify, how coalition partners interact in order to plan, execute and complete a transport process. Additionally transport business process reengineering is required to redesign and align the processes.

*VI-Outcomes:* Transport collaboration results in significantly increased ability to track and tracing, alleviated road congestions, yielded potentially large cost savings, improved internal and external customer service and reduced CO<sub>2</sub> emissions by bundling transport flows and optimizing transport network.

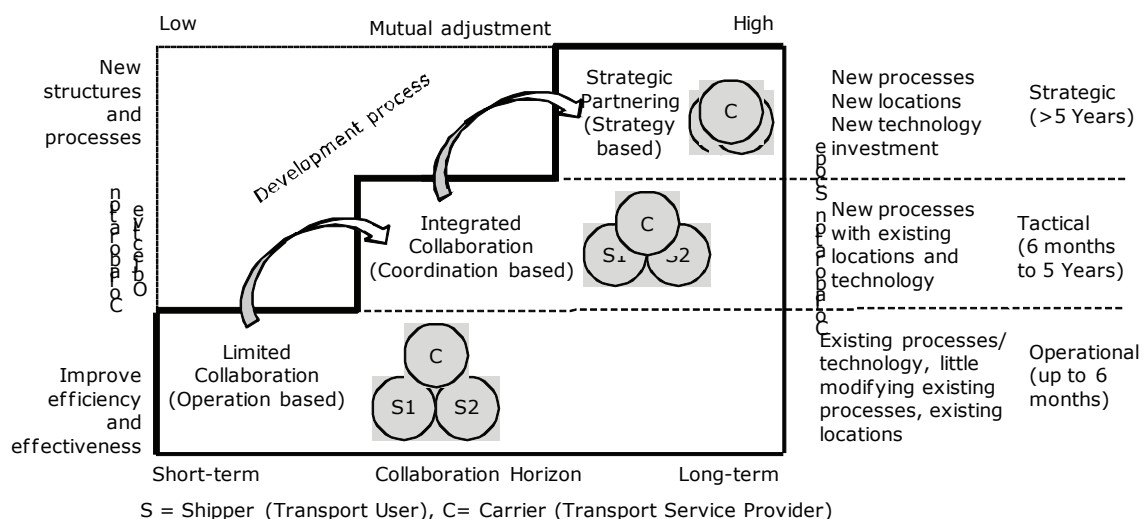


Figure 2: Collaboration ladder in heterarchical transport network

### (3) Classification procedures

The aforementioned six contents involve with internal and external perspectives. Internal perspectives refer the main initiators of the coalition: Transport Users (TU) and Transport

Service Providers (TSP), whereas external perspectives refer the important enablers of the coalition: Transport Network (TN), and Information and Communication Technology (ICT). The literature classification was made based on these six contents and four perspectives by applying three case studies. An observational research design combined with explorative case studies have been suggested for answering the below questions. As traditional ad-hoc methods, such as questionnaire designs, might not be supportive enough to present rigorous results. Yin (2003) noted that exploratory studies are primarily useful for the generation of hypotheses centered on the phenomena under investigation. This research questions are used with the six contents and four perspectives to generate the sub-contents.

The below open-ended questions have been asked to the participants in every case study.

- What were the drivers of your coalition?
- What were the facilitators of your coalition?
- How was the organizational alignment in transport network and with whom to integrate the processes
- What business processes were linked with each of the coalition partners?
- What level of integration and management were applied for each process link?
- What were the potential outcomes and benefits of your coalition?
- What was the role of ICT in your coalition?
- How was the transport network designed?

## **FINDINGS AND CONCLUSION**

Building wide-scale coalitions have become an emerging area in freight transport industry. Moreover, one of great possibilities for transport collaboration would simultaneously collaborate and compete. Therefore a group of shippers and carriers from the same or different supply chains can form coalitions in order to reap benefits from coordinated freight movement. The significant cost savings and advantages (highest reliability, reduced delivery time, reduced dwell time and dead-time, business process development, standardized procedures, on-time communication, profitability, reinforcement and expansion of relationship) can be achieved through these collaborative actions. In this research, 72 operating criteria as sub-contents are extracted for building coalition communities. The literature review findings are listed in Appendix. It can be observed that the criteria for *managerial involvement*, *organization fit* and *trust* are the most frequently investigated topics for inter-organizational relationships. The findings are categorized according to the three case study results. The distribution of sub-contents into the contents can be seen In Table 4. Here, the three coalitions classified the contents according to sub-contents with internal and external perspectives. Most of sub-contents can be referred in more than one contents and their culmination can be differed from one case study to another. The contents for business processes, drivers and decision entail more



sub-contents than others. These findings also show that the requirements of coalition could differ according to its type.

C	Coalition	Sub-contents numbers	C	Coalition	Sub-contents numbers
Drivers (I)	A	internal (1,3,6,8,9,10,11,12,13,20,21,23,24,31,36,38,42,43,51,57,58,61,62,65,67,68,70,71)	Decision (IV)	A	internal (9,35,54,61,65,67,68,70)
		external (1,3,6,8,9,16,19,22,23,32,36,44,45,46,48,53,55,56,59,60,61,63,64,65,66,67,68,69,72)			external (9,14,15,22,25,26,32,33,44,45,46,53,55,56,59,60,63,64,65,66,67,68,72)
	B	internal (1,3,6,8,9,11,12,13,20,23,24,31,36,38,42,43,51,57,58,61,62,65,66,67,68,70,71)		B	internal (9,54,61,65,66,67,68,70)
		external (1,3,6,8,9,16,19,23,32,36,44,45,46,48,53,55,56,59,60,61,63,64,65,66,67,68,69,72)			external (9,14,15,19,22,25,26,32,33,44,45,46,53,55,56,59,60,63,64,65,66,67,68,72)
	C	internal (8,10,11,12,13,20,22,23,24,31,38,43,51,61,62,64,67,70,71)		C	internal (35,54,61,70)
		external (1,9,16,19,23,32,36,55,56,59,61,65,68,72)			external (9,22,25,26,32,33,55,56,59,66,68,72)
Facilitators (II)	A	internal (6,9,10,11,12,13,20,21,24,27,31,35,36,41,47,50,57,58,62,71)	Business Processes (V)	A	internal (2,9,36,38,40,41,51,52,54,61,65,67,68,70)
		external (4,6,9,14,15,16,17,25,26,28,29,30,36,37,48,49,63,69)			external (2,4,9,17,18,25,26,28,29,30,32,33,36,37,44,45,46,48,49,53,55,56,59,60,61,63,64,65,67,68,69,72)
	B	internal (6,9,11,12,13,24,27,31,36,41,47,50,57,58,62,71)		B	internal (2,9,36,38,40,41,51,52,54,61,65,67,68,70)
		external (4,6,9,14,15,17,25,26,28,29,30,36,37,47,48,49,63,69)			external (2,4,9,17,18,25,26,28,29,30,32,33,36,37,44,45,46,48,49,53,55,56,59,60,61,63,64,65,67,68,69,72)
	C	internal (6,10,11,12,13,20,21,22,24,31,35,41,43,47,50,58,62,71)		C	internal (2,38,40,41,51,52,54,61,70)
		external (6,9,16,21,25,26,36,48,49,69)			external (9,25,26,29,32,33,36,37,45,48,49,53,55,56,59,63,64,65,67,68,69,72)
Components (III)	A	internal (5,10,11,12,13,20,21,22,24,27,31,34,35,39,40,41,43,47,50,52,57,58,62,71)	Outcomes (VI)	A	internal (1,2,7,23,34,38,43,51,54,57,58,61,70)
		external (5,14,15,16,19,22,47)			external (1,7,16,18,23,49,53,55,56,64,72)
	B	internal (5,11,12,13,20,21,22,24,27,31,34,35,39,40,41,43,47,50,52,57,58,62,71)		B	internal (1,2,7,23,34,38,43,51,54,57,58,61,70)
		external (5,14,15,21,22,47)			external (1,7,18,23,49,53,55,56,64,72)
	C	internal (5,10,11,12,13,20,24,31,35,39,40,41,47,50,52,57,58,62,71)		C	internal (2,23,38,43,51,54,58,61,70)
		external (5,16,19)			external (1,16,23,49,55,56,64,72)

Table 4: Classification of key operating criteria according to case studies

The findings can be characterized by the composition of the coalition. However, the relationships between these criteria should be carefully investigated and strategically aligned each other. Therefore, future work is going to address the development of the strategic alignment framework.

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### Appendix: The Key Operating Criteria in Transport Collaboration

#	Sub-contents	Abbr.Code	References	Contents	Perspectives
1	Accelerated ROI	ROI	[2,8,14]	I,VI	TN,ICT,TU,TSP
2	Asset optimization	ASSET	[10,14,18,26,28]	V,VI	TN,TU,TSP
3	Benefit sharing	BENSHR	[27]	I	TU,TSP
4	Business architecture	ARCH	[4,7,8,37]	V,II	ICT
5	Business need	BUSSN	[39]	III	TN,ICT,TU,TSP
6	Capacity	CAPA	[5,18,28]	I,II	TN,ICT,TU,TSP
7	Carbon footprint (sustainability)	SUST	[6,3,20,23]	VI	TN,ICT,TU,TSP
8	Cohesion	COHE	[32]	I	TN,TU,TSP
9	Collaborative technology	COLLTECH	[11,40]	I,II,IV,V	ICT,TU,TSP
10	Commitment	COMM	[5,8,19,30,39]	I,II,III	TU,TSP
11	Common interest	COMINT	[5,27,39]	I,II,III	TU,TSP
12	Company size	SIZE	[3,13,28,29,30]	I,II,III	TU,TSP
13	Competitive positioning	COMP	[4,28,22]	I,II,III	TU
14	Control right	CRIGHT	[1,27,28,32]	I,II,III,IV	TU
15	Control risk	CONT	[6,13]	II,III,IV	TU
16	Cost sharing	COSTSHAR	[2,21]	I,II,III,VI	TU
17	Data connectivity	DATACONN	[11]	II,V	ICT
18	Data optimization	DATAOP	[11]	V,VI	ICT
19	Delegations	DELE	[32]	I,III	TU
20	Dependency of partners	DEPEN	[19]	I,II,III	TU,TSP
21	Equal compensation	EQCOMP	[6,13,28]	II,III	TN,TU,TSP
22	Feasibility	FEA	[13,21,28]	I,II,III,IV	TN,ICT
23	Financial and eff. savings	FINEFF	[2,14]	I,VI	TN,TU,TSP
24	Financial Performance	FINANS	[2,14,28]	I,II,III	TU,TSP
25	Flexibility in processes	FLEXP	[5,9,34,40]	II,IV,V	TN,ICT
26	Flexibility in toolset	FLEXT	[6,18,40]	II,IV,V	TN,ICT
27	Hierarchical structure	HIERAR	[32]	II,III	TN,TU,TSP

28	ICT compatibility	ICTCOMP	[21,28]	II,V	ICT
29	Immature standards	IMMSTD	[11,21]	II,V	ICT
30	Information quality	INFQ	[28]	II,V	ICT
31	Information sharing	INFSHAR	[5]	I,II,III	TU,TSP
32	Infrastructure	INF	[1]	I,IV,V	TN,ICT
33	Integration level	INTL	[5,8,15,34,38]	IV,V	TN,ICT
34	Intellectual property	INTELPR	[28,30,34]	III,VI	TU,TSP
35	Interdependence	INTERD	[5,13,27]	II,III,IV	TN,ICT,TU,TSP
36	Internal connection	INTERCON	[5,13]	I,II,V	ICT,TU,TSP
37	Interoperability	INTER	[11,25]	II,V	ICT
38	Lead time	LEADT	[2,28,40]	I,V,VI	TU,TSP
39	Leadership	LEAD	[1,5,27]	III	TU,TSP
40	Level of orientation	ORIENT	[8,13,26]	III,V	TU,TSP
41	Management involvement	MNG	[3,4,5,22,25,27,28,30,33]	II,III,V	TU,TSP
42	Manpower training	MANTR	[3,15]	I	TU,TSP
43	Market structure	MARKET	[28]	I,III,VI	TU,TSP
44	Multi-agent technologies	MULTAG	[7]	I,IV,V	ICT
45	Network design	NTW	[35,36]	I,IV,V	ICT
46	New technology application	NEWTECH	[21,28]	I,IV,V	ICT
47	Openness of communication	OPENCOM	[5,13,27,28]	II,III	TN,TU,TSP
48	Operating environment	OPENW	[3,8,28]	I,II,V	TN
49	Op. interface and synchronization	OPINTF	[32]	II,V,VI	TN,ICT
50	Organizational fit	ORGFIT	[3,4,6,11,13,14,28,29,34]	II,III	TU,TSP
51	Overall efficiency	OVEFF	[10,14,26,39]	I,V,VI	TN,TU,TSP
52	Performance measures	PERFM	[5,28]	III,V	TU,TSP
53	Predictability	PREDIC	[10,40]	I,IV,V,VI	TN
54	Profitability	PROF	[13,33]	IV,V,VI	TU,TSP
55	Reliability	RELI	[14,24,28,40]	I,IV,V,VI	TN,ICT
56	Replenishment Length	REPLEN	[9,40]	I,IV,V,VI	TN
57	Reward sharing	REWSHR	[38]	I,II,III,VI	TU,TSP
58	Risk sharing	RISKSH	[38]	I,III,VI	TU,TSP
59	Safety and security	SASE	[11,20,36,39]	I,IV,V	ICT
60	Scalability	SCALA	[5,6,18,40]	I,IV,V	ICT
61	Service level	SERV	[10,14,26,28,39]	I,IV,V,VI	TN,TU,TSP
62	Skill set	SKILL	[3,33,13,16,22]	I,II,III	TU,TSP
63	Standardization	STD	[11,16,21,30]	I,II,IV,V	ICT
64	System performance	SPER	[28]	I,IV,V,VI	ICT

65	Technological Capabilities	TEHCAP	[5,21,27,28,30]	I,IV,V	ICT,TU,TSP
66	Technological investment	TECHIN	[21,28,34]	I,IV,V	ICT,TU,TSP
67	Technology usage	TECHUS	[3,13,17,30]	I,IV,V	ICT,TU,TSP
68	Transparency	TRANS	[27,5,13,24,27]	I,IV,V,VI	ICT,TU,TSP
69	Transport chain	TRCHAIN	[18,20,27]	I,II,V,VI	TN, TU, TSP
70	Transport cost	COST	[13,28,30,33]	I,IV,V,VI	TU,TSP
71	Trusting relationship	TRUST	[13,20,24,27,30,32,39]	I,II,III	TU,TSP
72	Variability	VAR	[10,28,40]	I,IV,V,VI	TN, TU

\* Information and communication technologies (ICT), Transport Network (TN), Transport User (TU) and Transport Service Providers (TSP)

# **MODELLING READY MIXED CONCRETE TRANSPORTATION PRODUCTIVITY WITH HYBRID MODELS BASED ON NEURAL NETWORK AND REGRESSION MODEL**

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## **ABSTRACT**

This paper proposes a transportation productivity prediction model for ready mixed concrete business. This research develops quantitative techniques, which are a combination of neural network and regression analysis in order to model ready mixed concrete delivery. Two hybrid models i.e. (1) hybrid neural network-regression model; and (2) hybrid multiple regression-neural network model are conducted to predict transportation productivity. Seven dependence variables are employed to this study which is concrete volume, delivery distance, batching time, travelling time, waiting time, pouring time, and returning time. The results indicate that the collected data were complied well with both models. The prediction performance of both models was compared to determine an optimal model by using mean absolute percentage error (MAPE) and root mean square error (RMSE). The results reveal that MAPE and RMSE of hybrid neural network-regression model are lower than hybrid multiple regression-neural network. As such, it can be claimed that hybrid neural network-regression model is more capable for modeling transportation productivity of ready mixed concrete than hybrid multiple regression-neural network.

**Keywords:** Ready Mixed Concrete, Multiple Regression, Neural Network, Hybrid Model

## **INTRODUCTION**

Ready mixed concrete is a common building material used in the construction of commercial and industrial buildings, roadways, infrastructure and other structures. Ready mixed concrete is a perishable product which is a custom specified and availability of ingredients. Ready mixed concrete delivery has limitation due to capacity of plant batching and delivery time. At the same time, customer behavior constraints are variety such as demand fluctuation, placement size, quantity ordered of a specific mix, delivery location and timing, ordering, accuracy of quantity and so on (Tommelein, D. and Li, A. 1999). Normally, ready mixed concrete industry is produced concrete at several plants, which have to deliver at customers' construction job sites using a mixer truck fleet in a timely with



cost-effective management (Schmid, V. et al., 2009). Based on operations of large size ready mixed concrete company located in Bangkok, Thailand, the variation of ready mixed concrete delivery is crucial. The delivery process is complicated, which has many consideration factors involved including amount of concrete volume, concrete batching time, traveling time, delivery distance, waiting time at job site, concrete pouring time and truck return time. So, it is necessary to manage organization's resources in order to minimize the total delivery time and maximize concrete delivery volume. As the result, the rate of delivery of ready mixed concrete is employed to measure transportation productivity (Graham, L.D. et al., 2006). In this research, hybrid models based on neural network and regression models are employed for modeling ready mixed concrete delivery, which consists of 3 procedures. The modeling procedure starts with data identification and preparation that describes affecting factors for measuring productivity performance. The next step is to model and predict ready mixed concrete delivery by using 2 hybrid models i.e. (1) hybrid neural network- regression model and (2) hybrid multiple regression-neural network model. The last step is to compare performance accuracy of both hybrid models.

## **LITERATURE REVIEW**

Ready mixed concrete transportation is necessary to monitor the whole processes, which are involved producing, dispatching and delivery ready mixed concrete. Schmid, V. et al. (2009) presented hybrid solution approach for ready mixed concrete delivery which integrated optimization and heuristic techniques. The information of multi-commodity flow component and variable neighborhood search component are considered to find the reasonable time. The high quality solutions of both components are acceptable of producing feasible solution. On the other hand, the integrated approach is more effective which outperformed 6% more than an average. Graham, L.D. et al. (2006) presented neural network methodology by using feed forward and Elman networks in order to optimize modeling. The integrated of layers, training algorithms, hidden neurons, activation function and format data were evaluated and validated with five goodness of fit test. Two and three layer of feed forwards had shown the best results of concrete placed productivity. Asbach, L. et al. (2009) presented model of logistics problem during delivering concrete from concrete production plant to customer construction site by using a specific local search approach to solve problem occurring in complex scheduling. They integrated programming model to solve a huge problem from practice. An algorithm can be extended without many changes of interactive, dynamic and online approach by considering only customers, which are not currently being delivered. Lu and Lam (2009) presented

simulation and optimization of computer system, which provided decision support making the best operation strategy for plant managers in order to deliver concrete to multiple site customers. The computer system can be used in practical to serve as a useful parallel to the actual system for enhancing performance, optimizing the best concrete production scheduling, planning truck fleet resources and arranging the pouring time. Silva, C.A. et al. (2005) presented a complex optimization of ready mixed concrete production and distribution using combination of genetic algorithm and ant colony optimization. The problem was related with scheduling and routing problem that have to consider a trade-off production and delivery cost. The problem was solved by a combination of GA and ACO, which was reduced of concrete delivery cost in practice but increased the computational time. Naso, D. et al. (2004) presented meta-heuristic approach based on a hybrid evolutionary algorithm combined with constructive heuristics for addressing just in time production and delivery with the time constraints on both early and late supply. The hybrid approach was proved to be an effectively scheduling algorithm based on a realistic model of ready mixed concrete distribution. The combination of GA and heuristics was guaranteed the determination of feasible schedule. The proposed method showed the superior performance on the amount of trucks and safety margins for minimizing the effects of transportation delay. Zhang, Y. et al. (2011) presented mathematical model in order to improve the operation of ready mixed concrete production as well as to decrease the dispatching cost of the whole delivery process. They considered both trucks and pump dispatching. Genetic algorithm was proposed to solve the large size of solution space.

To sum up, this research differs from previous works in several aspects. The related work of ready mixed concrete delivery problem consider mainly on simulation, optimization, and heuristics techniques, while multiple regression (MR) and artificial neural network (ANN) are applied to predict and model in many applications; for instance Chanprasopchai, P. & Atthirawong, W. (2012a;2012b) combined these two methods to predict commercial margin in ready mixed concrete business. However, few of them pay attention in a ready mixed concrete delivery problem. In the light of these gaps, this research conducts hybrid models based on MR and ANN for modeling ready mixed concrete transportation productivity. The benefit of the estimate model will be useful for the management to plan an operation and its resources, thus avoiding shelf-life problem.

## **READY MIXED CONCRETE TRANSPORTATION**

Ready mixed concrete has a shelf life roughly around one and a half hour (ASTM C94). As a result, both a batching plant and customers need to rely on time restriction constraint.

Ready mixed concrete batching is operated at plants that mixing ingredients to be concrete and then load concrete into the mixer truck. The quality and quantities are fully control by computer system, which can be automated or semi-automated procedure. The concrete batching time is measured in order to optimize operation plan. Concrete is transited to construction site by using mixer truck that is considered by their volume, delivery distance and traveling time. In many cases, the construction site is not ready to pour concrete into customer’s construction structure. Therefore, it is necessary to wait at job site until pouring process can be fixed. The main effects of pouring time are the difference of experience, equipment and behavior of customers. The last step is return mixer truck to the batching plant. Table 1 demonstrates the specific variables in this research in order to measure transportation performance of ready mixed concrete business. Figure 1 shows the whole concrete delivery process starting from batching plant transformed raw material into concrete, truck mixer traveling to construction site, waiting time in order to pour concrete at job site, pouring concrete, until returning truck to batching plant respectively.

**Table 1:** The specific variables in this research

Variables	Descriptions	Unit
Concrete volume	The amount of ready mixed concrete is placed at the construction job site.	Cubic mater
Delivery distance	The length of transportation route is measured between batching plant and construction job site.	Kilometer
Batching time	The time is needed to blend raw material to be concrete including unload into mixer truck.	Minute
Travelling time	The duration is used during transit concrete from batching plant and construction job sit.	Minute
Waiting time	The period is measured from mixer truck arrived at construction site until unload concrete.	Minute
Pouring time	The period is determined unloading concrete from mixer truck to the construction site.	Minute
Returning time	The duration is used during return truck from construction site and batching plant.	Minute
Productivity	The transportation productivity is calculated to measure the performance.	Cubic meter per hour

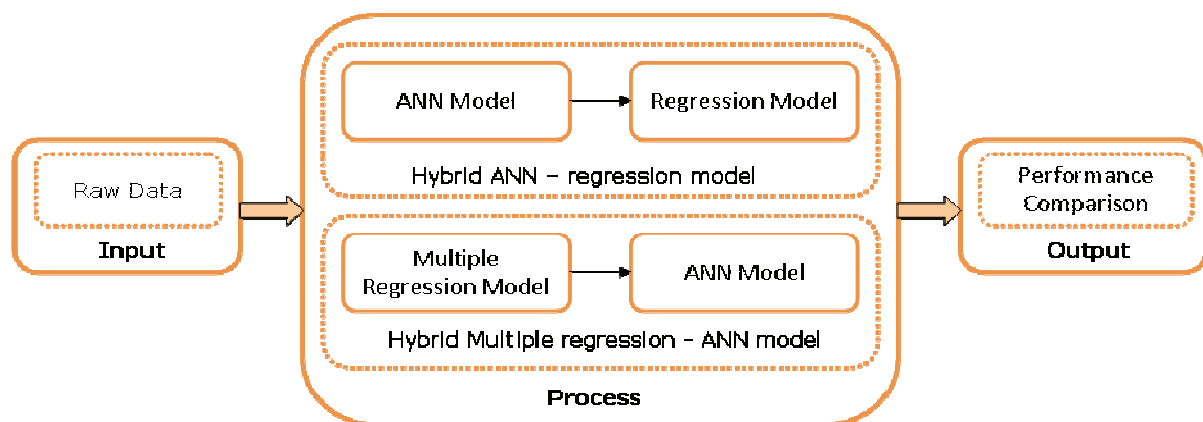


**Figure 1:** Ready mixed concrete delivery process

The risk of ready mixed concrete goods is that should be laid in the period without any loss of time to avoid the reduction in workability, setting and stiffening of concrete. The time interval in between batching and pouring concrete is very critical. The delay in delivery process reduces the workability of ready mixed concrete, which effect to the difficulty in placement of ready mixed concrete. At the same time, the delay lead to the initial setting and stiffening of concrete, that effect to be unusable goods. So, the transportation of ready mixed concrete must be performed as rapidly as possible.

### MODELING METHODOLOGY

This research presents two approach hybrid models in order to optimize ready mixed concrete transportation modeling, which are (1) hybrid neural network- regression model and (2) hybrid multiple regression-neural network model. The experimental procedure is demonstrated in Figure 2.



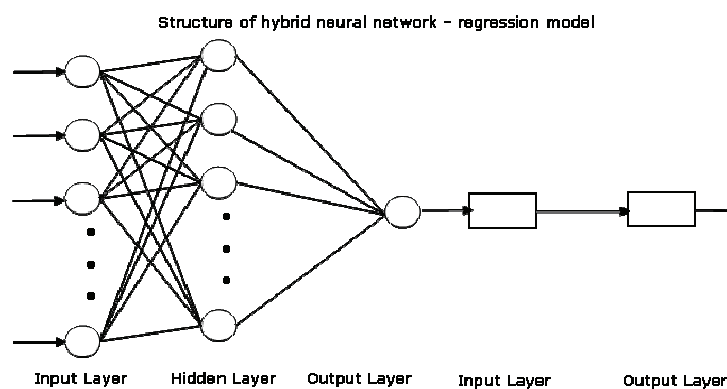
**Figure 2:** Experimental procedure

Hybrid models have been proposed to predict transportation productivity. Regression /multiple regression models have achieved successes based on linear relationship. On the other hand, ANN model is more suitable for non-linear relationship. However, neither regression/multiple regression nor ANN is suitable for all aspects. Hybrid model can combine the strength of regression/multiple regression and ANN models to capture both linear and non-linear relationship. The hybrid model can be written as following:

$$Y_t = N_t + L_t \quad (1)$$

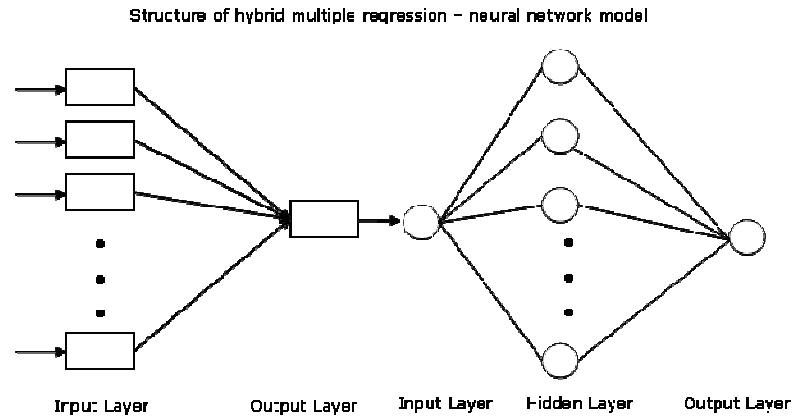
$Y_t$  is the hybrid model at time t,  $N_t$  is the non-linear component at time t and  $L_t$  is the linear component at time t.

Hybrid ANN-regression model is the combination of ANN with regression model. The non-linear and linear component can solve and analyze the data in order to evaluate transportation productivity. The proposed hybrid ANN-regression scheme is displayed in Figure 3.



**Figure 3:** Structure of Hybrid ANN-regression model

The hybrid multiple regression - ANN model is combined multiple regression with ANN model, which has the same component as hybrid ANN-regression model. The proposed hybrid multiple regression-ANN model is demonstrated in Figure 4.



**Figure 4:** Structure of Hybrid multiple regression-ANN model

The actual and predicted data are then compared performance accuracy. In this research, the performance accuracy of both models are measured using mean absolute percentage error (MAPE) and root mean square error (RMSE), which are calculated by equations (2) and (3) respectively.

$$MAPE = \frac{1}{n} \sum_{t=1}^n \left| \frac{Y_t - \hat{Y}_t}{Y_t} \right| \times 100 \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{t=1}^n (Y_t - \hat{Y}_t)^2} \quad (3)$$

## DATA COLLECTION

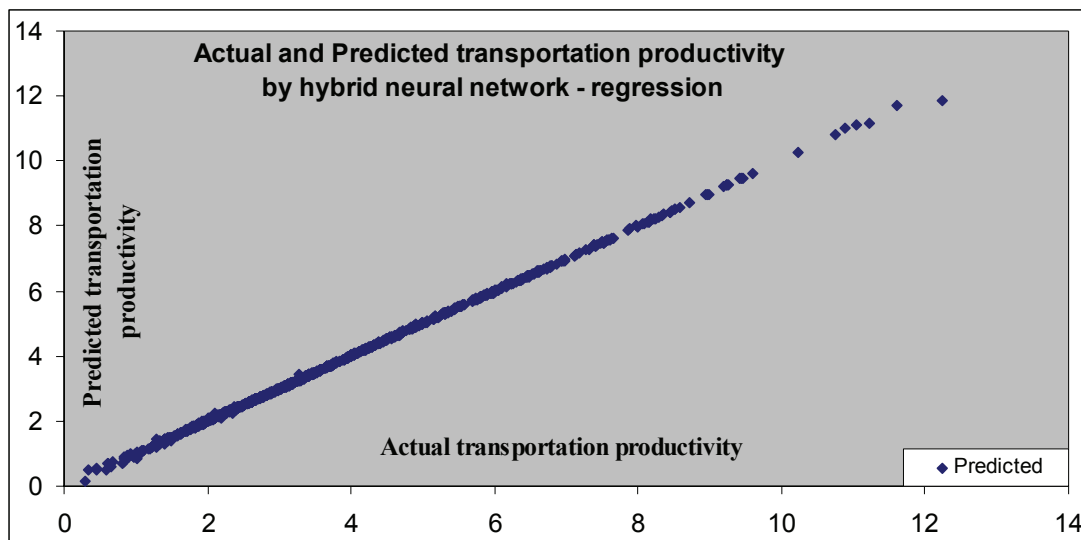
The study area is located in greater Bangkok, which has traffic congestion. The mixer truck has capacity only 6 cubic meters because of law and regulation. The total 843 trips of ready mixed concrete delivery with all relevant variables were recorded in order to develop both hybrid models. Table 2 shows statistical information values, which are collected in the field.

**Table 2:** The statistical values of ready mixed concrete delivery

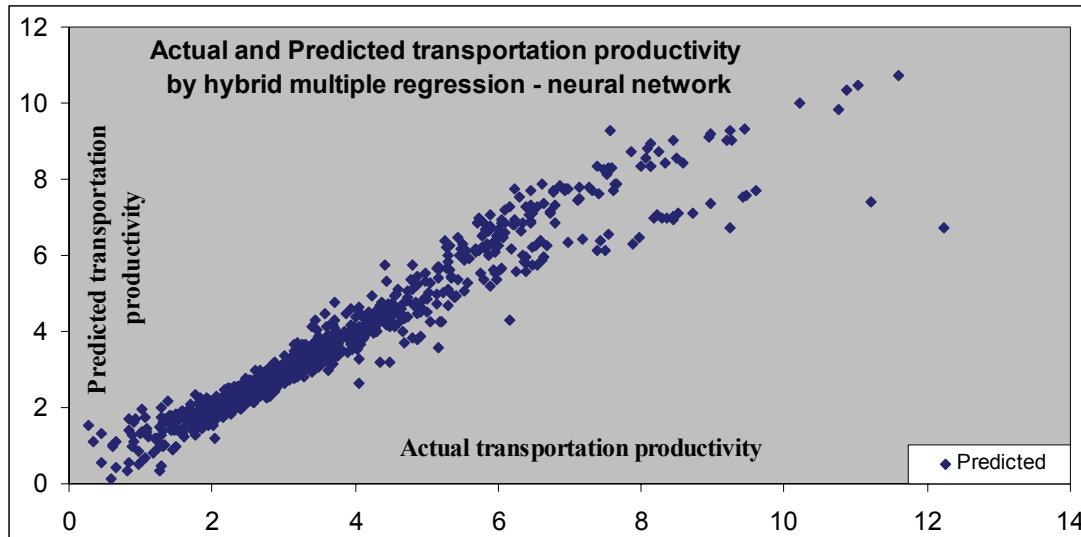
Variables	Unit	Min	Max	Mean	Median	SD
Concrete volume	m <sup>3</sup>	0.25	6.00	4.66	5.00	1.30
Distance	Kilometer	0.10	23.15	7.49	6.50	6.27
Batching time	Minute	2.22	46.22	14.85	14.17	6.32
Travelling time	Minute	1.00	95.00	17.80	16.02	10.94
Waiting time	Minute	0.02	97.12	12.52	7.05	14.47
Pouring time	Minute	0.47	155.78	27.45	28.43	25.53
Returning time	Minute	1.00	92.02	15.26	13.00	12.14
Productivity	m <sup>3</sup> /hour	0.28	12.24	3.75	3.28	1.98

## RESULTS

In order to develop ready mixed concrete transportation modeling, transportation productivity is assigned to be a dependent variable. On the other hand, concrete volume, delivery distance, batching time, travelling time, waiting time, pouring time and returning time are considered as independent variables. Hybrid neural network–regression and hybrid multiple regression–neural network models were developed in order to evaluate ready mixed concrete transportation productivity. The results of predicted transportation productivity compared with the actual transportation productivity from hybrid neural network–regression model and hybrid multiple regression–neural network model are shown in Figure 5 and 6 respectively. The results shown that the relationship between actual and predicted transportation productivity of hybrid neural network–regression model is closely to linear relationship, which is better than hybrid multiple regression–neural network model.



**Figure 5:** Performance of hybrid neural network–regression model



**Figure 6:** Performance of hybrid multiple regression–neural network model

### PERFORMANCE EVALUATION

The performance measurements of transportation productivity from both models are analyzed by using mean absolute percentage error (MAPE) and root mean square error (RMSE). Table 3 shows the comparison results of MAPE and RMSE values of both hybrid models. The result indicates generally that the error from hybrid neural network–regression model is lower than hybrid multiple regression–neural network model. Therefore, the results reveal that hybrid neural network–regression model is better performance than multiple regression-neural network.

**Table 3:** Performance comparison

Models	RMSE	MAPE
Hybrid neural network–regression model	0.028724	0.860352
Hybrid multiple regression-neural network model	0.519427	10.830478

### CONCLUSIONS

Ready mixed concrete delivery models are implemented to investigate productivity, which depend on variant variables including concrete volume, delivery distance, batching time, travelling time, waiting time, pouring time and returning time. Hybrid neural network–regression and hybrid multiple regression–neural network models were developed to predict the ready mixed concrete transportation productivity using actual collected data from the case company in greater Bangkok, Thailand. The actual values and predicted transportation productivity values were compared in order to measure the performance of the both models. The predicted values of hybrid neural network–regression



model were found closely to the actual values. Moreover, the values of RMSE and MAPE of hybrid neural network–regression model is lower than hybrid multiple regression–neural network model. As the results, it can be concluded that hybrid neural network–regression model has better performance to develop ready mixed concrete transportation productivity modeling than hybrid multiple regression–neural network model. Continued work on improving network performance may lead to more accuracy results; for instance using recurrence or reusing past inputs and outputs. Furthermore, the ready mixed concrete transportation productivity model can be considered other techniques in order to improve performance e.g. response surface methodology, other hybrid models and so on.

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## Section 8 – Retail Logistics

### ORGANISATION OF LOGISTICS ACTIVITIES IN RETAIL COMPANIES – A PARADOX PERSPECTIVE

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#### INTRODUCTION

Many retail companies increasingly take control of their supply chains, and are no longer to be considered “the extended arm of the suppliers” (Renko & Ficko, 2010; Sandberg, 2013). As a result, the importance of the management of logistics activities increases (Schramm-Klein and Morschett, 2006; Sandberg, 2013). The term “logistics” is here given a wide definition, including traditional logistics activities such as transportation and inventory management, but also management of product range, forecasting, and promotional campaigns.

Along with the increased importance of these activities, a challenging task for management is how to organise them (Boute et al., 2011). The purpose of this paper is to better understand the complexity when organising logistics activities in retail companies. As a theoretical basis a paradox perspective (Smith & Lewis, 2011; Poole & Van de Ven, 1989), stemming from organisational theory, is applied. According to the paradox perspective different organisational arrangements of logistics activities could be mirrored in different paradoxes, i.e. different organisational tensions with conflicting interests, sometimes also referred to as dualities, dilemmas or dichotomies. More specifically, this paper seeks to identify some of the main paradoxes present in modern retail organisations. The empirical basis is a multiple case study of six Swedish retail companies from a variety of retail sectors, including fashion, food, automotive spare parts, and textiles.

#### METHODOLOGY

This research is based on an explorative, multiple case study (e.g. Yin, 2003), in which the organisation of logistics activities in six Swedish retail companies has been focused. As a theoretical foundation for the article, a relatively new theoretical framework of organisational paradoxes has been applied.

An interview guide with open-ended questions has been developed. In line with the exploratory research approach, the interview guide was developed on a general level as a means to capture logistics activities as the interviewees themselves describe them (Yin, 2003). Additional to the interview guide, in order to ensure validity, the term logistics was explained by providing a general definition of logistics during the interviews. The data collection was conducted during autumn 2012. In total 10 managers at six retail companies with self-service outlets operating on the Swedish market (and sometimes in other markets as well) were interviewed. The companies have been selected to ensure coverage of a broad range of different sectors as a means to facilitate external validity.

As suggested by Yin (2003) within-case analyses were first conducted before making cross-case comparisons and pattern-matching activities. Stuart et al. (2002) claims the process of interpreting qualitative data to be "a challenge of making sense from chaos" (p. 427). To decrease complexity in the analysis process the within case analysis has been kept separated from the cross-case analysis. The main output of the within-case analysis was a map over the major logistics activities and what function that was responsible for each activity.

These six maps served to develop an initial, in-depth understanding of each case company's logistics activities. The map-making increases the validity of the results as it is an important step in establishing the much-discussed "chain of evidence" (e.g. Yin, 2003; Gibbert et al., 2008) between the empirical data collection and findings. The map-making was also a suitable start for the cross-case analysis (Yin, 2003) where the case companies' different logistics activities were grouped into a total of 14 major logistics activities. Also the names of departments at the companies' were partly renamed and grouped together, with the purpose of giving them about the same function/task in each company respectively.

### **ON PARADOX THEORY**

The paradox theory, sometimes also referred to as duality-theory (Evans et al., 2002; Graetz & Smith, 2009) or ambidexterity theory (Nosella et al., 2012) is a new theoretical field for logistics research and has its roots in organisational theory. Organisational research has undergone many development steps, where the earliest research generation opted for an answer to the question "Is A or B the most effective way"? Next generation in turn, which was developed during the 1960s, often described as contingency theory, instead asked "Under what conditions is A or B the most effective way?", thus assuming that one alternative always is preferable to select. The contingency theory has been relatively often applied in logistics research during the years, perhaps most frequent when combined with the strategy-structure-performance paradigm during the 1990s (e.g. Stock et al., 1998).

Opposed to contingency theory where an optimal organisational solution is opted for, the paradox perspective seeks instead to explore how organisations can apply to competing demands simultaneously (Smith & Lewis, 2011; Evans et al., 2002). Smith & Lewis (2011) define paradox as "*contradictory yet interrelated elements that exist simultaneously and persist over time*" (Smith & Lewis, 2011, pp. 382). This definition emphasise that the underlying logic for each element may seem rational when dealt with them separately, but appears to be inconsistent when juxtaposed against each other.

The basis for this theoretical perspective was developed during the 1980s as a new means to capture and understand the underlying logic for effective organisations, in particular in times with rapid change (Evans et al., 2002; Graetz & Smith, 2009). In a dynamic environment, organising raises multiple tensions that needs to be tackled. The paradox theory does not advocate the search for an optimum position among tensions valid for all future. Rather, it seeks to balance the tensions on a continuous basis in line with a turbulent environment (Nosella et al., 2012; Smith & Lewis, 2011; Poole & Van De Ven, 1989). In fact, a "dualities aware perspective" (Graetz & Smith, 2009) goes even further and does not only recognise the tensions, but also exploit and encourage the creativity and dynamism enhanced by the presence of tensions (Graetz & Smith, 2009; Poole & Van de Ven, 1989).

Paradoxes are present in all organisations of which some of them are salient and others are latent until environmental conditions such as scarcity of resources make them explicit to management. Management could also themselves make paradoxes explicit through "paradox cognition" and subsequent rhetoric (Smith & Lewis, 2011; Graetz & Smith, 2009). Managing paradoxes is a challenging task for many companies (Seo et al., 2004),

and a first step could be to make them more explicit by adopting what Graetz & Smith (2009) labels a “dualities aware perspective”.

To further structure the paradox theory, Smith & Lewis (2011) identify four categories of paradoxes (Smith & Lewis, 2011, pp. 383):

1. Learning (knowledge): Efforts to adjust, renew, change, and innovate foster tensions between building upon and destroying the past to create the future
2. Belonging (identity/interpersonal relationships): Identity fosters tensions between the individual and the collective and between competing values, roles, and memberships
3. Organising (processes): Structuring and leading foster collaboration and competition, empowerment and direction, and control and flexibility
4. Performing (goals): Plurality fosters multiple and competing goal as stakeholders seek divergent organisational success

Apart from these categories, there are also natural tensions between the categories. For instance, there is a tensions between investing in new knowledge and technology and the demand for short-term financial results.

## **FINDINGS**

### **Logistics activities in the retail supply chain**

A cross case analysis of the organisational maps from the within case analysis indicated that logistics activities in the retail supply chain process could be grouped into 14 general activities to be the most important ones in the retail supply chain process. The informants also indicated where in the organisation, i.e. in what department, the activities were executed. Table 1 shows the activities and the different departments involved in the execution.

Table 1: The most important activities in the retail supply chain process and the involved departments

	Involved departments				
	Logistics	Purchasing	Sales (including the stores)	Marketing	General management
Supplier relationships, sourcing, CSR, etc		<b>X</b>			
Transportation planning supplier -> CW	<b>X</b>	<b>X</b>			
Call-offs Supplier -> CW	<b>X</b>	<b>X</b>			
Category management and product range		<b>X</b>	<b>X</b>	<b>X</b>	
Sales forecasts	<b>X</b>	<b>X</b>	<b>X</b>		
Pricing		<b>X</b>	<b>X</b>		
Import administration, customs etc.	<b>X</b>	<b>X</b>			
Central warehouse (CW) operations	<b>X</b>				
Transportation planning CW -> store	<b>X</b>				
Call-offs CW->store	<b>X</b>		<b>X</b>		
Planning of order quantities CW -> store	<b>X</b>	<b>X</b>	<b>X</b>		
In-store logistics routines, e.g. stacking	<b>X</b>		<b>X</b>		
Planogram, store concept, etc.			<b>X</b>	<b>X</b>	<b>X</b>
Campaigns and promotions	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	

Activities in the retail supply chain process

Although the informants have used different terms, the case companies' logistics scope in terms of retail supply chain activities were relatively homogenous, i.e. at a company level, they seem to execute the same activities. At this overall level, this could also be considered an expected finding: it is likely that retail companies, independent from industry, needs to handle the flow of goods, purchase and order goods, plan for the deliveries to the stores, etc. Interestingly, the logistics scope seems to cover a wide range of different types of activities. Not only the more traditional logistics activities are covered by the informants, but also many marketing-related ones such as the management of campaigns, forecasts and store concepts. This indicates how closely intertwined logistics and marketing and sales activities are in a retail environment.

Despite the similarities of the scope of logistics activities, there are differences among them concerning who in the company, i.e. what department, is responsible for the execution of them. In particular, except for a logistics department, the purchasing and sales departments are involved in the execution of logistics activities. Whereas purchasing may seem natural to take part in the execution of logistics activities, the sales department is perhaps less expected. The sales department is however in all 6 companies responsible for the daily management of store operations (sometimes referred to as "the sales organisation"). As a result, operations inside the stores fall often, but not always into the responsibility of the sales department.

## **Paradoxes**

In accordance with the paradox theory presented above, the case companies' organisational design of their logistics activities shows that there are several possible ways to organise logistics activities. This research has investigated the reasons for having different departments responsible for different activities. The reason for a certain organisational belonging of an activity is obviously many times grounded in tacit, historical motives. As a result, many of the informants have not been able to justify their organisational design in an objective manner. However, there are also many examples of when clearly motivated explanations are present, and where organisational tensions and conflicting goals are made very clear by the informants. Below some of the most debated paradoxes are discussed.

### *Campaigns*

Recent years there has been a significant increase in the amount and frequency of promotional campaigns (Ettouzani et al., 2009; McKinnon, 2007). Promotional campaigns can be initiated either by retailers, by suppliers, or by a collaborative effort between the two (Ettouzani et al., 2009). Campaigns are time-limited promotions with relatively short life-cycles aimed at stimulating increased sales in an existing store, attract customers to a new store, etc. Informants in this research confirm campaigns as an important activity in the case companies. As Table 1 indicates, there is a wide range of possibilities to organise the planning and responsibility for promotional campaigns in the case companies.

In terms of Smith & Lewis' (2011) categorisation, the campaigns is above all to be considered a belonging paradox, in which the local, individual store's (or region's) interests are opposed to the company as a whole. Informants witness about different opinions concerning the number of campaigns, the possibility and support for the launch of local, individual campaigns parallel to the national (centralised) ones. Overall, although the merits of having a centralised management of campaigns is clearly acknowledged also at a local store-level, there is a continuous struggle between the local needs and the overall company goals.

Another tension that arises due to campaigns could also be viewed as a performance paradox (Smith & Lewis, 2011) as there is a conflict in goals between increase of sales opted for by sales department on the one hand, and logistics-related costs on the other. During the interviews, informants have indicated that since campaigns are in first hand initiated to stimulate sales and for instance increase the market share, there is a risk that other logistics activities such as transportation planning and warehouse handling operations will be negatively affected due to less opportunities to effectively plan these activities. This means that the accurate associated costs for a campaign are seldom captured in a satisfactory way. Hidden logistics costs may even jeopardize the profitability of a promotional campaign.

### *Product range*

Of great importance to logistics, even though it is not a traditional logistics activity, is to manage the product range, being part of the category management concept. Despite its importance, little research attention has been given to the questions of product range (Fisher & Vaidyanathan, 2012). As is shown in Table 1, there are several organisational alternatives for how to manage the product range.

In terms of Smith & Lewis (2011) paradox-categories, performance as well as learning paradoxes are present in the management of the product range. The performance paradox consists of the traditional conflict between purchasers' wish for a limited scope

of products to be purchased in order to enhance economies of scale in purchasing, and the wish for the sales- and marketing organisation to offer a wide range of products in the local store. In companies with the product range to be decided by the purchasing department, in addition to economies of scale in the purchasing (including negotiation power), informants also mention that a greater variety of products drive different kinds of logistics and supply chain costs, e.g. obsolescence, inventory carrying costs, rush orders, etc. In the case companies with product range decisions to be made in the sales- or marketing organisation the category management and product range is viewed as a driver for competitive advantage, enabling the stores a customer- and service-oriented offering. The product range is here considered part of a larger offering, which also includes services such as installations, financial solutions, knowledge of the sales staff, etc.

The learning paradox captures the dynamism of the product range, acknowledging that there is a constant need to change the product range. When product range is controlled by the purchasing department, a close control of suppliers' new products can be ensured. New products and trends concerning e.g. production material could be better planned for in advance. On the other hand, in companies with product range decisions to be made by the sales- or marketing department, the proximity to the customers and ability to scan future customer demands are considered as the major source of inspiration and change.

#### *The order and delivery cycle between central warehouse and the store*

From a retailer's perspective, logistics means the successful management of the costs of transportation, handling and storage, whilst ensuring high on-shelf availability (Ferne & Sparks, 2009). This is typically accomplished through collaboration and integration across functions in the supply chain, from the supplier, via central warehouse and further on to the store and the shelf. In many of the companies there is not one department that has the entire control of all activities in this critical process. Whereas the central warehouse is normally responsible for the inventory carrying costs and the handling costs in the central warehouse, and manages the physical picking, packing and transportation to the store, the responsibility for call-offs and decisions concerning order quantities could be managed by the stores individually, or by a sales department centrally. In addition, the purchasing department could also be involved when it comes to the order quantities.

The tensions related to the order and delivery cycle are complex, and spans over belonging as well as organising paradoxes using Smith & Lewis' (2011) classification. From a traditional logistics point of view, the informants are well aware of the advantages of giving the sole responsibility of the order and delivery process to the logistics department: this facilitates the smooth planning and execution of supply chain activities, as well as cost control and improved delivery service performance. Three of the companies however, have despite these advantages another organisational design due to the fact that the development of the in-store logistics activities, and the store concept is controlled by sales department (or the marketing department). As the store concept to a large extent influence order quantities (via e.g. use of planograms, design of shelves, etc) these companies judge a proper alignment between store concept development and order quantities from CW to the stores to be more crucial than giving the control of the entire order and delivery cycle to the logistics department.

## **CONCLUSIONS**

For many retail companies the organisation of logistics activities is a critical issue for management. In line with the applied theoretical lens of paradox theory, the organisational designs of the six case companies include a number of organisational paradoxes or tensions with conflicting goals. This research identifies three areas of particular interest, including the management and responsibility for promotional campaigns, product range, and the order- and delivery cycle. These three areas



constitute great challenges when organising retail logistics activities. In line with a paradox theory, it is not possible, or even meaningful, to search for an “optimal solution”. Rather, the three areas need to be fully understood, including a mapping of underlying conflicting interests, and thereafter get management attention to balance conflicting goals.

To borrow in new theoretical frameworks into the logistics research arena could be beneficial (Stock, 1997). This research attempts to introduce a new theoretical field into the logistics research body. A paradox perspective, or having a “duality aware perspective” (Graetz & Smith, 2009) “helps to resolve the ostensible contradictions inherent in organizing forms by providing a conceptual explanation for its presence.” (Graetz & Smith, 2009, pp. 13).

As such, although not addressed as a research question, the paper raises the question about the applicability of a paradox theory in logistics research. Though this paper is a modest, first attempt, the results indicate the paradox perspective to be a promising continuation of the use of organisational theories in logistics research. The major advantage consists of using the paradox framework as a tool for the illumination – and classification – of existing conflicts present in the organisation. Logistics researchers may already be well informed about the existence of these conflicting goals and interests, but have so far lacked a more formal theoretical framework for further clarification of them.

In a wider sense, the paradox theory as it is presented in organisational theory, is indicated as a new era of research where previous contingency-based research is downplayed in favour of a more dynamic view of organisational research (Graetz & Smith, 2009). In this research, organisational design does not become a question of finding an optimal, final design, but to balance conflicts inherent in the organisation. This development goes hand in hand with the development in the strategic management field of research, where dynamic capabilities theory has been developed from the more static resource-based view of the firm (Pavlou & El Sawy, 2011). For logistics researchers, the development in organisational as well as strategic management theory signals the need for new theoretical lenses where dynamism could be managed and understood.

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# **INSTORE LOGISTICS AND SHELF READY PACKAGING AND THEIR IMPACT ON ON-SHELF-AVAILABILITY**

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## **ABSTRACT**

This paper discusses the relationship between shelf ready packaging (SRP) and on shelf availability (OSA) for grocery retailing. We examined in particular the impact of SRP on OSA, the quality dimensions of SRP and the attributes that facilitate the shelving process. The research design consists of an empirical observation of OSA and analytical process modeling including and empirical assessment of the SRP-quality of 19 selected products of the largest German hypermarket.

## **INTRODUCTION**

The avoidance of out-of-stock (OOS) situations is a crucial issue when it comes to the optimization of fast moving consumer goods (FMCG) supply chains (see e.g. Aastrup and Kotzab 2010). An OOS can be either a percentage of articles that are not on a shelf at a given point in time (= store-based definition) or as the number of times consumers are looking for products in a store and do not find these products on the expected shelf (= shopper-based definition) (see Gruen 2007).

No matter how one looks at it, the consequences of OOS are significantly impacting the profitability of FMCG supply chains. A study by ECRE (2003) analyzed the customer reactions on OOS situations and found out that a large share of customers would postpone their purchase or would try to purchase another brand or a different size of the article. However a share of 30 % of the customers would either go to a different store or would decide to decline their purchase. These two customer reactions would directly lead to lost sales that impact the retailer as well as the manufacturer of the product (see also Corsten and Gruen (2003).

The "counterpart" to OOS is on-shelf-availability (OSA) that is defined as "*the measure of a product being available for sale to a shopper, in the place he expects it and at the time he wants it.*" (Mitchell 2011, 2). This means that products need to be in consumers' reach in an order-ready state and the consumer needs to be aware of this. If this is not the case, the consumer perceives an out-of-stock situation (OOS). Both measures, OSA and OOS, are probabilities and depend on the execution of instore logistics (Studer and Greco 2009, 52; Chopra and Meindl 2007, 77). Fisher et al. (2006), Corsten and Gruen (2003) or Raman et al. (2001) showed e.g. that better order management, better management of promotions and inventories as well as better shelving processes and improved processes in the receiving areas as well as better integration with upstream supply chain partners and their activities lead to higher OSA and lower OOS.

Another possibility to decrease the OOS problem and further increase the OSA is shelf-ready packaging (SRP). However, even though a lot of manufacturers and retailers are using SRP, we can still find gaps in the shelves. According to Haubenreißer (2013) this may be due to mismatching packaging sizes and shelf positions that are caused by lacking harmonization of secondary packaging sizes with the dimensions of the shelves.

Based on this problem background we were interested to examine the relationship between quality of SRP and OSA. So far, literature has dealt with instore logistics processes in general (e.g. Kotzab and Teller, 2005), improvement areas of supply chain delivery concepts on instore logistics in general (e.g. Placzek 2007, Sauerberg 2009). One focus area of (Curşeo et al. 2008; van Zelst et al., 2008 or van Donselaar et al. 2006) has been the shelving process and how the improvement of this process leads to decreased costs.

When it comes to SRP, we were not able to find specific research dealing with the relationship between SRP and OSA. Bergmann (2008), ECR-Europe (2006) or Korzeniowski (2009) examined the optimal design of SRP and assumed a positive impact of SRP on OSA. Based on these research gaps we wanted to empirically identify the potential of SRP and its influence on increasing OSA.

The overall goal of our project is to identify and to analyze product specific context factors for the assessment of packaging related recommendations for increasing the efficiency of instore logistics. Specifically we set up the following research questions:

1. What is the impact of SRP on OSA?
2. What are the quality dimensions of SRP?
3. Which SRP attributes facilitate the shelving process?

## **MODEL DEVELOPMENT AND MEASUREMENT**

Our frame of reference is embedded in the context of instore logistics, SRP and OSA (as introduced by Kotzab and Teller 2005). Instore logistics is the internal logistics system of a retailer and refer to all logistics processes at the point-of-sale (POS). The overall goal of instore logistics is to achieve a steady order fulfillment preparedness by ensuring a continuous demand-driven OSA (see Fisher et al. 2006 or Kotzab and Teller 2005).

SRP can be seen as an optimization tool for instore logistics as the overall goal of SRP is to develop package sizes that enable simple processes at the POS. In other words, SRP helps to offer retail store ready package units for simple shelf replenishment (e.g. Hertel et al. 2011, 220). SRP refers to five areas, which are labeled as easy identification, easy opening, easy disposal, easy shelving and easy shopping (Bergmann 2008). For improving the efficiency of the instore logistics processes, it is necessary that staff is able to identify the merchandise quickly by offering high visibility of the necessary information. For shelving the items quickly it is recommended that trays can be opened easily and to be shelved easily so that the filling process can be speeded up. Empty trays shall be quickly disposed and finally, consumers shall be able to locate and to take the products without problems from a shelf (ECRE 2006).

SRP requires though a heavy coordination and harmonization effort for package standardization. Up until now it is not clearly defined if a simple tray replenishment in form of moving secondary packaging into the shelves can be defined as SRP or if it also includes merchandising units, throw away packages or reusable packaging (ECRE 2006, 16).

In order to answer our research questions we set up a research instrument, which aimed to specify OSA improvement potentials through SRP. The approach included the following components:

- a) Measurement of OSA by examining a difference between SRP and non-SRP products. The hypothesis behind this step was that the OSA of SRP products is significantly higher than the OSA of non-SRP products.
- b) Measurement of the SRP quality by analyzing the attributes of SRP in terms of simplifying the shelf replenishment process. Also here the hypothesis was that

shelving processes of SRP products are significantly easier than the processes of non-SRP products.

- c) Process analysis by modeling the shelving processes. The hypothesis behind this step was that the shelving processes of SRP products included less steps than the shelving processes of non-SRP products.

When it comes to the OSA measurement, we were able to identify several approaches. While Kotzab et al. (2007) let employees assess their perception on the OSA, Helnerus (2007), Placzek (2007) or Sauerberg (2008) measured the OSA by physically checking individual products which should lead to a more objective result. For the purpose of our study, we followed the objective approach and developed a tool for measuring the OSA of selected products in a store.

For assessing the quality of the SRP processes we expanded a checklist developed by ECR Switzerland (2012). The checklists referred to all the easy areas of SRP but we distinguished thereby between handling dependent and handling independent SRP processes and we measured their existence with a nominal scale out of which we further developed an SRP quality index. This index expresses the relationship between the sum of the number of positive answers and the total number of SRP items. Furthermore the processes of selected items were modeled and analyzed, based on Business Process Model and Notation 2.0

In addition we developed one questionnaire and one interview guideline for mapping the impressions of the involved retail personnel when it comes with their work with SRP and the relation to OSA.

## **METHODOLOGY**

Our project was executed in close cooperation with a German leading grocery retailing company. All data was collected between 22.01.2013 to 06.02.2013 in the largest hypermarket of Germany, which is located in the Bremen area (larger than 14,000 sqm sales floor area). Together with the management of the retailer, 18 products were selected and they all referred to packaged products including coffee (4), oil (2), orange juice (3), rice (4), tomato sauce (3) and pasta fix (2). All categories included branded and private label products and their OSA was measured three times a day during opening hours between 22.01.13 and 28.01.13.

The questionnaire for the involved employees was checked with the local work council and distributed to 49 employees via the work council. 26 full questionnaires were returned by February 6, 2013. In the same time period the qualitative interviews were conducted in the break room with several employees. All selected products were examined once on their handling-dependent SRP quality. This was done during the first OSA measurement. The handling-independent SRP quality was performed as an optical check of the presentation of the product in the shelves. Due to unexpected difficulties we focused our modelling approach to four products including 2 branded and 2 retail brand items. This process was done once on 25.01.2013.

The handling-independent SRP quality was assessed by checking the presentation of the product in the shelves during the data collection time period. The handling-dependent SRP quality was assessed once by observing the shelving processes of all products. For the process modelling, the packaging specific attributes of four selected products were observed.

We received furthermore some empirical data from the retail merchandise system such as POS data for the analysed products for the analysed period of time as well as for the business year 2011.

## RESULTS

In our project, the OSA refers to the average shelf inventory level of an article. During the research period we were not able to identify any OOS, however the OSA level changed depending on the product. The OSA ranged thereby between 223.7 and 10.1 (both private label products).

When comparing the OSA with the POS data, we could identify a very interesting characteristic. There we were able to see that the analysed products were rather slowly moving. This was also validated by checking the annual sales volume. For only one product we could see that the sales volume was above the OSA level. This means that the majority of the products will probably not require a huge replenishment effort.

Figures 1 and 2 present the average daily OSA levels and their daily sales volume for two products (tomato sauce; private label and branded product) over the observation period.

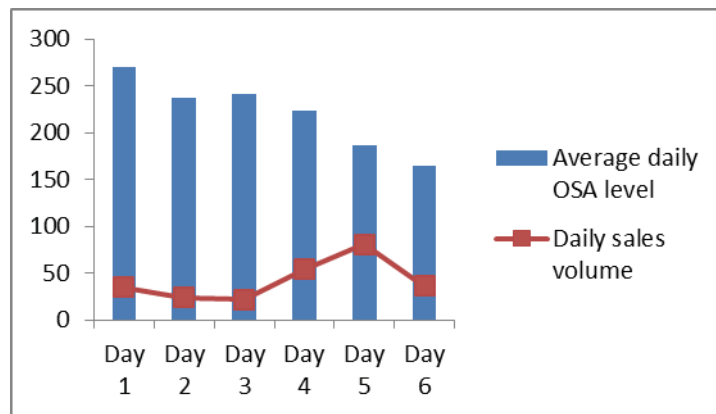


Figure 1: Average daily OSA level and daily sales volume for private label tomato sauce

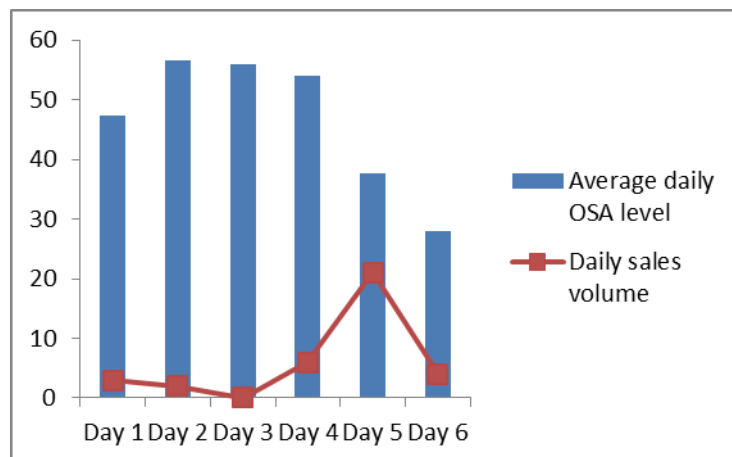


Figure 2: Average daily OSA level and daily sales volume for branded tomato sauce

We can see in both cases that the daily sales volume would probably not require such high OSA levels. The peak sales is only on Day 5 (which is a Saturday). During the observation period, we were also able to identify some effects that have not been considered during the planning period. Sometimes products were presented also in additional displays and it was difficult to distinguish between the normal and additional product presentation. Some of the products seem to be replenished by rack jobbers as we could observe unexpected increases in the OSA levels.

The results of our employee assessment can be summarized as follows. 24 of 26 people state that the share of replenishment activities in relation to the total working time is more than 50 %. 8 out of 10 people are aware of the three levels of SRP (trays, merchandising, and reusable packaging).

Nearly all of them are aware of the internal guidelines for replenishment. These results give a good indication of a high employee awareness of SRP and its handling. However, only 1 out of 2 people confirm an easy opening of trays as well as of a problem-less handling with SRP. The majority of the respondents (17 of 26) state that the trays need further handling processes in order to make the product easy to shop.

The major problems refer to removal of additional packaging (e.g. foil). This leads to hold-ups in the process. When it comes to out-of-stock-situations, most of the times the respondents indicate not to report those. They are trying to fill the gap immediately (22 of 26 respondents). Even though this is a clever move, the company is missing to know the root causes for OOS. Overall, we were not able to see that SRP was highly appreciated by the employees. Half of the respondents still think that the packaging is difficult to handle.

When looking at the handling-dependent SRP quality, the calculated index ranged between 0.76 and 0.95 with an average index value of 0.89 (std.dev. 0.06). The handling-independent SRP quality index was a little bit lower ranging between 0 and 0.76 with an average index value of 0.62 (std.dev. 0,2). Here we could see that some products' packaging had some improvement potentials.

The combined SRP quality index showed an average of 0,75 (std.dev. 0.11). Overall we were not able to distinguish a significant difference between either SRP and non-SRP or branded or private label products. We could also observe that the SRP trays did not meet all requirements of the store. Sometimes, the front side of some trays was scrapped in order to have a better store presentation. In other cases, the full potential of SRP was not utilized as products were taken out of half empty trays and put in front of full trays.

The observation of the specific replenishment processes that were chosen for process modeling showed that it was not possible to see a significant difference in the process flow between SRP and non-SRP products. In both cases we observed some feedback loops referring to the placing of the packaging in order to remove flaps or due to grabbing items from the shelves in order to move new items into the shelves.

However, we could see that SRP avoids the placing of individual articles, meaning that larger units are replenished which leads to a higher OSA level. It was however difficult to see whether SRP leads to significant reductions of waste in the process flow and in packaging.

## **DISCUSSION, CONCLUSION AND OUTLOOK**

During our research project, we experienced some challenges. First, we were surprised that it was not easy to identify SRP and non-SRP products. It took the management of the retailing company some time to select appropriate products. Based on this, we were then very astonished that the SRP quality indices for handling-dependent and handling-independent indicators were not showing substantial differences between the analyzed products.

There we were rather seeing that the packaging standards vary heavily. These results were confirmed by the results of the employee survey where employees were still complaining on the difficulties during shelving processes even though the products were SRP-ready. It seems that there is still a huge effort necessary for harmonizing packaging standards with shelf and store dimensions. Here we gained some insight through our

process flow modeling approach. However it would be necessary to examine this in more depth as one can expect that the execution of the process flow can differ depending on the employee's ability to execute the process.

We also found out that it was very difficult to measure a direct effect of SRP on OSA in the given setting of a hypermarket. We were expecting different patterns sales volumes that have an effect on OOS and OSA. Here, we were confronted with a slow moving sales pattern. For only one product, the sales volume was larger than the OSA level.

Taking this into account, our results present valuable pilot study insights into the analysis of the relationship between SRP and OSA. Though our results show an improvement potential through SRP, no explicit cause and effect path can be identified so far. In a further step, we are interested to analyze the efficient execution of SRP following the suggestions of Reiner et al. (2013) and use their DEA-approach idea. As an input to the DEA model we suggest one input factor describing the SRP-quality, the timely effort for shelving and the individual number of facings to be shelved and one input factor including the number of facings in the shelves and the shelf dimensions. Both factors would represent capacity indicators. The output factors would refer to the OSA and the sales volumes.

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## **DOES FIRM SIZE AND SUSTAINABLE PERFORMANCE IN FOOD SUPPLY CHAINS: INSIGHTS FROM GREEK SMEs**

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### **INTRODUCTION**

According to Carter & Rogers (2008), sustainable supply chain management (SCM) is “the strategic, transparent integration and achievement of an organisation’s social, environmental, and economic goals in the systemic coordination of key interorganisational business processes for improving the long term economic performance of the individual company and its supply chains”. They posit that a deliberate long-term strategy combining environmental and social aspects of sustainability, that extend beyond a firm’s boundary with economic objectives, helps firms to mobilise those supply chain activities that directly support sustainability. Similarly, performance measurement systems that include sustainability considerations can be a driver for sustainability performance improvement (Angell & Klassen, 1999). Small and medium-sized enterprises (SMEs) are not immune from these pressures, particularly given that their total (cumulative) impact on sustainability is high (Gadenne *et al.*, 2008). Moreover, many SMEs have not progressed in the adoption and development of sustainable supply chain practices due to the upfront cost of greening and although the literature is rich on supply chain performance measurement in general (e.g. Gunasekaran *et al.* 2004), there is a dearth when more specific contexts are considered. Furthermore, while the literature on various aspects of sustainability strategy creation in SMEs (e.g. Gadenne *et al.*, 2008) and/or food supply chains (e.g. Jamsa *et al.*, 2011) has recently started to develop, a careful examination of the literature indicates only a handful of contributions that have specifically addressed sustainability performance measurement in supply chains in the context of SMEs (Gunther & Kaulich, 2005), and none in the context of SMEs in the food supply chain; thus, a major gap exists in the literature. This gap is confirmed in a recent work by Bititci *et al.* (2012) who conducted a literature review synthesis and stressed that further challenges in relation to performance measurement include performance measurement in SMEs and sustainability issues in performance measurement. Our work addresses this shortcoming by investigating sustainability performance, analysing the effect of firm size at SME level (micro, small, medium) on various appropriate indicators developed through a careful review of sustainability measures for food supply chains found in the literature. In accordance with the definition of SMEs from the European Commission (European Commission, 2005), the micro category included firms employing less than 10 persons and with annual turnover or annual balance sheet totalling no more than €2 million. The small category included firms employing less than 50 persons and with annual turnover or annual balance sheet totalling no more than €10 million. In the medium-sized

category, we included firms with less than 250 employees and with annual turnover no more than €50 million or annual balance sheet totalling no more than €43 million (European Commission, 2005).

### **SUSTAINABILITY PERFORMANCE MEASURES FOR FOOD CHAINS**

We have adopted a performance measurement framework widely used (Aramyan *et al.*, 2007). The framework allows chain-wide measurement, comprises four categories (*efficiency, flexibility, responsiveness* and *product quality*, Aramyan *et al.*, 2007) and a total of 18 sustainability measures relevant to food industry supply chains are identified (Table 1).

**Table 1: Sustainability supply chain performance measures**

<b>Performance Element</b>	<b>Measures</b>
Efficiency	Production / operational / raw materials cost Storage cost Delivery and distribution cost Waste Financial cost Gross profit margin
Flexibility	Flexibility in extra volume orders Flexibility in delivering in extra point of sales
Responsiveness	Responsiveness in the arranged lead time Responsiveness in delivery in terms of arranged point of sale Responsiveness in delivery of ordered product (exact code, quality, etc.)
Quality	Quality of the firm's product Product conservation time Consistency of traceability system Storage and delivery conditions Quality of packaging
Total supply chain	Firm's perception of its own supply chain performance Firm's perceptions of market opinion regarding its chain performance

The first group are efficiency measures. Specifically, the food supply chain's production processes and delivery systems can have a significant negative impact on the environment if not designed effectively and managed efficiently (Angell & Klassen 1999). Delivery and distribution costs are clearly a critical efficiency measure in food supply chains of all types and sizes whilst storage costs in the food supply chain are an important indicator of food supply chain members' sustainability performance. Waste is one of the most pervasive sustainability issues in food supply chains and minimisation is frequently identified in the literature as a core measure for environmental sustainability in food production (Maloni & Brown, 2006). The financial cost associated with the administration of food supply chain operations is an important sustainability performance indicator. To these preceding cost-based and waste efficiency measures we add a sixth, namely gross profit margin. This was identified by Kolk (2004) as a key sustainability measure. Flexibility is widely used as group of performance indicators in the supply chain literature (Aramyan *et al.* 2007). Two flexibility measures are particularly important for SMEs operating in food supply chains: flexibility in delivering to extra points of sale, and flexibility in extra volume orders (Ilbery & Maye, 2005). Our third group of measures are concerned with responsiveness, which reflects the ability of the food chain to deliver a high customer service (Shepherd & Gunter, 2006). We propose three measures of responsiveness: the responsiveness in meeting the arranged lead times, the responsiveness in delivering to the arranged point of sales (location), and the responsiveness in delivering the product as ordered (correct type and quantity). The fourth category of sustainability measures concern product quality. Product quality is widely recognised and used as a key sustainability performance criterion (Aramyan *et al.*, 2007). Final product quality is highly dependent on primarily product conservation time.

Product conservation time refers to the length of time a food product within the food supply chain maintains the desired properties and characteristics before it starts to deteriorate and become unusable. Lastly, raw material quality is important for final product quality. In this paper, raw material quality is considered as part of the final product quality and, hence, it is not examined separately. A near mandatory requirement in food supply chains is food traceability and it is considered as an essential sustainability measure. In addition, regulatory and/or consumer demands for recyclable or returnable packaging and for clearer information on the nutritional and dietary characteristics of the food products has heightened the importance of the need for packaging of good quality (Angell & Klassen, 1999). To the preceding 16 food supply chain sustainability measures we have added two complementary measures. These recognise explicitly the importance of the chain members' own evaluation of its overall performance as a contributor to the sustainability of the food supply chain of which it is a part, but also these members' own evaluation of the possible external market's opinion of that performance. Overall, we seek responses to the following research questions:

1. How do micro, small and medium-sized members of the Greek food chain perform in key sustainability measures?
2. Are there any differences in the sustainable performance of the Greek food chain with respect to firm size?

## METHODOLOGY

We employed a structured questionnaire survey divided in two sections. The first section included questions on five performance categories (efficiency, flexibility, responsiveness, quality and total supply chain). Efficiency indicators were assessed in terms of percentage of the firm's turnover while the remaining indicators were evaluated on a seven point Likert scale (1= Extremely satisfactory performance, 7= Extremely unsatisfactory performance). The second section included questions on demographic representation in order to analyse differences in performance with respect to micro, small and medium-sized firms. The questionnaire was pre-tested through a qualitative stage whilst the final quantitative stage focused on the key members of the Greek food chain in relation to firm size. It is worth noting that many changes have taken place in this food chain during the past two decades including the advent of many international manufacturers and retailers, the significant investment in logistics infrastructure by the major retail multiples and the use of sophisticated systems (see Bourlakis *et al.* 2012). Firms were identified through relevant directories (e.g. ICAP Business Directory, ICAP 2007) and our sample covered a representative number of firms from various supply chain stages and sectors involved. Initially we contacted each firm by telephone to identify the potential respondents – "key informants". As we were focusing on SMEs, the appropriate "key informant" was normally the general manager or the owner of the firm who was deemed appropriate to answer our questionnaire due to their expert knowledge of their organizations. Data collection was carried out by a professional research agency by means of a Computer-Aided Personal Interviewing system (CAPI) and we only solicited one response per each firm sampled in the survey. Questionnaires were answered through telephone surveys representing every Greek region. On many occasions, these "key informants" suggested other SMEs who might be interested to participate in our work and, they also suggested other SMEs they were collaborating with. As a result, we analysed 997 responses. Finally, we employed analysis of variance (ANOVA) to determine whether the chain members have significant differences with respect to the 18 indicators. ANOVA is a method for investigating statistical differences in performance and many examples are found in the supply chain literature (Lai *et al.*, 2004).

## EMPIRICAL FINDINGS

Table 2 shows the number of firms in each key food supply chain stage and their size.

**Table 2: Firms classified according to supply chain role and firm size**

	<b>Growers</b>	<b>Manufacturers</b>	<b>Wholesalers</b>	<b>Retailers</b>	<b>Total</b>
Micro	139	82	233	137	591

	<b>Growers</b>	<b>Manufacturers</b>	<b>Wholesalers</b>	<b>Retailers</b>	<b>Total</b>
Small	19	108	167	25	319
Medium	6	36	34	11	87
Total	164	226	434	173	997

On average, turnover is between €500,000–€1,000,000 for growers, manufacturers and wholesalers. For retailers, the average turnover is €200,000–€500,000.

### ***Firm size versus supply chain role***

We analysed the differences among micro, small and medium-sized firms with respect to their supply chain role, namely, growers, manufacturers, wholesalers and retailers in order to examine the effect of firm size on performance. The following subsections report the significant differences observed between micro, small and medium-sized firms in terms of the individual performance measures. Out of these measures, we report those where we observed significant differences in terms of firm size in the ANOVA test (at 0.05 significance level). The best performer for each indicator is emphasized in bold.

#### **Growers**

The growers in the Greek food supply chain do not generally have processing operations, with the micro growers serving primarily local markets. Table 3 reports significant differences in performance measures when growers' data is analysed using ANOVA. There are two statistically significant differences in the sustainable performance measures with respect to firm size for the growers. Small growers perform better in terms of flexibility in extra volume orders and consistency of traceability system and average scores indicate "very satisfactory" perception in terms of these two variables. There are no statistically significant differences in performance between micro firms and the total sample or between medium firms and the total sample in terms of flexibility in extra volume orders and consistency of traceability system.

**Table 3: Differences between micro, small and medium-sized growers**

<b>Performance Measure</b>	<b>Micro (n=139) Mean (SD)</b>	<b>Small (n=19) Mean(SD)</b>	<b>Medium (n=6) Mean(SD)</b>	<b>Total (n=164) Mean (SD)</b>
Flexibility in extra volume orders	3.26 (2.02)	<b>1.95 (1.03)</b>	3.67 (1.75)	3.12 (1.97)
Consistency of traceability system	2.53 (2.03)	<b>1.26 (0.56)</b>	1.50 (0.84)	2.35 (1.93)

An explanation of these findings may relate to the fact that the micro growers do not have enough capacity (and flexibility) to cope with changes in orders as they produce small volumes. These firms have not developed their supply chain and they often do not have the time, resources or information (and flexibility) to deliver the requested extra volume orders. Medium-sized firms may be negatively impacted by their size in relation to flexibility because although they have larger capacity in comparison to micro and small firms, they usually deal with large, multiple retailers or wholesalers and their production capacity is not always sufficient to accommodate extra, large orders from these firms. In terms of the consistency of using a traceability system, micro firms are likely to be operating in local markets, in relatively short supply chains giving products to local buyers; hence, they may be less likely to use consistent traceability systems. Conversely, small and medium-sized growers may be shipping greater distances serving large retailers and wholesalers concerned with traceability implementation.

#### **Manufacturers**

Following an ANOVA test for manufacturers (Table 4), we observed a successful performance of micro firms in terms of gross profit margin. These micro manufacturers

sell primarily to local and regional retailers and wholesalers and they usually manufacture niche products which command larger profit margins. The latter may also explain the high profit margin exhibited by small manufacturers. Medium-sized manufacturers distribute to larger national retailers and wholesalers and could be therefore facing higher financial demands. For the remaining measures exhibiting statistical significance, medium-sized firms outperform small and micro manufacturers.

**Table 4: Differences between micro, small and medium-sized manufacturers**

<b>Performance Measure</b>	<b>Micro (n=82) Mean (SD)</b>	<b>Small (n=108) Mean(SD)</b>	<b>Medium (n=36) Mean (SD)</b>	<b>Total (n=226) Mean (SD)</b>
Gross profit margin	<b>12.05(10.5)</b>	11.2(10.7)	5.60 (3.33)	10.56(10.0)
Flexibility in extra volume orders	3.02 (1.70)	2.23 (1.2)	<b>2.17 (1.6)</b>	2.51 (1.55)
Flexibility in delivering in extra POS	3.04 (1.83)	2.33 (1.6)	<b>2.08 (1.3)</b>	2.55 (1.69)
Quality of packaging	2.21 (1.64)	1.85 (1.4)	<b>1.44 (0.7)</b>	1.92 (1.44)
Firm's perception of chain performance	2.46 (1.17)	<b>1.97(0.7)</b>	<b>1.97 (0.7)</b>	2.15 (0.95)
Firm's perceptions of market opinion regarding its supply chain performance	2.37 (1.18)	<b>1.98(0.8)</b>	<b>1.97 (0.9)</b>	2.12 (1.03)

In comparison to growers, manufacturers are more likely to have operational systems in place and, therefore, they are more flexible to accommodate changes in customer volume orders and points of sales. Specifically, medium-sized manufacturers outperform micro manufacturers in most sustainability indicators given in Table 4. This can be related to higher economies of scale achieved in various operations including packaging. In terms of the firm's perception of its own supply chain performance and the firm's perceptions of market opinion regarding its supply chain performance, micro manufacturers perform worse than small and medium-sized manufacturers. Micro manufacturers may be aware of that, they may have resource constraints as well as limited use of relevant systems and processes. Equally, medium-sized manufacturers perform slightly better than small manufacturers in these two indicators and are possibly aware of their ability to attract higher economies of scale (and scope by manufacturing products in similar categories) in their operations.

### **Wholesalers**

Small wholesalers perform better in most performance measures with the exception of quality of packaging (Table 5). Specifically, packaging in the food sector requires specific know-how and medium-sized wholesalers may be able to have better access to the necessary resources than micro and small wholesalers.

**Table 5: Differences between micro, small and medium-sized wholesalers**

<b>Performance Measure</b>	<b>Micro (n= 233) Mean (SD)</b>	<b>Small (n=167) Mean (SD)</b>	<b>Medium (n=34) Mean (SD)</b>	<b>Total (n=434) Mean (SD)</b>
Consistency of traceability system	2.24 (1.55)	<b>1.80 (1.3)</b>	2.03 (1.82)	2.05 (1.50)
Quality of packaging	3.40 (2.44)	2.58 (2.25)	<b>1.71 (1.1)</b>	2.95 (2.35)
Firm's perception of its own supply chain performance	2.36 (0.98)	<b>2.07 (0.84)</b>	2.47 (1.40)	2.26 (0.98)
Firm's perceptions of market opinion regarding its supply chain performance	2.31 (1.14)	<b>2.08 (0.90)</b>	2.53 (1.21)	2.24 (1.07)

Micro wholesalers are less inclined to have consistent traceability systems. This may be related to the fact that they serve primarily the local market. It may also be the outcome of the low profit margins that wholesalers command, making the use of traceability

systems, which are quite expensive, possibly prohibitive. Equally, small wholesalers (and medium) are more inclined to achieve consistency in terms of traceability.

### Retailers

Micro retailers outperform small and medium-sized retail firms in terms of gross profit margin (Table 6) and this can be explained by the fact that micro retailers are generally operating in remote and distant areas and sometimes they have a monopoly by being the only retailer – store in a village. Waste performance of medium-sized retailers is much better than the micro and small firms. Medium-sized retailers manage larger volumes of product than the micro and small retailers and offer many promotions and product discounts. Therefore, they should be more proactive (and could perform better) in terms of reducing waste in their operations. Finally, small firms perform better in terms of flexibility in extra volume orders and responsiveness in delivery in terms of the ordered type of product (exact code etc).

**Table 6: Differences between micro, small and medium-sized retailers**

Performance Measure	Micro (n=137) Mean (S D)	Small (n=25) Mean (SD)	Medium (n=11) Mean (SD)	Total (n=173) Mean (SD)
Gross profit margin	<b>14.81 (11.5)</b>	5.67 (5.28)	5.44 (3.64)	12.66 (11.0)
Waste	6.95 (6.54)	3.58 (3.82)	<b>2.00 (1.8)</b>	5.95 (6.13)
Flexibility in extra volume orders	2.80 (1.57)	<b>1.80 (0.9)</b>	2.55 (1.75)	2.64 (1.54)
Responsiveness in delivery of ordered product (e.g. exact code)	1.77 (1.11)	<b>1.48 (0.6)</b>	2.55 (2.30)	1.77 (1.18)

### Greek Food Chain

We also examined the differences between micro, small and medium-sized firms in the whole sample in order to expose the under- and over-performing firms. Out of the 18 performance indicators, we only report those where we observe significant differences in terms of firm size (at 0.05 significance level, see Table 7).

**Table 7: Significant differences with respect to firm size (ANOVA test)**

Performance Measure	Micro (n= 591) Mean (SD)	Small (n=319) Mean (SD)	Medium (n=87) Mean (SD)	Total (n=997) Mean (SD)
Production / operational / raw material cost	<b>43.74 (27.9)</b>	49.53 (26.2)	50.93 (29.65)	46.32 (27.67)
Gross Profit margin	<b>12.52(11.3)</b>	11.45 (11.4)	8.10 (8.60)	11.83 (11.22)
Delivery & distribution cost	6.55 (6.70)	8.40 (7.05)	<b>5.61 (6.99)</b>	7.07 (6.90)
Flexibility in extra volume orders	2.82 (1.69)	<b>2.25 (1.27)</b>	2.49 (1.78)	2.61 (1.59)
Flexibility in delivering in extra points of sales	3.04 (1.89)	<b>2.38 (1.54)</b>	2.52 (1.73)	2.78 (1.80)
Responsiveness in delivery in terms of arranged point of sale	2.00 (1.43)	<b>1.76 (1.12)</b>	1.95 (1.36)	1.92 (1.34)
Responsiveness in delivery product	2.07 (1.62)	<b>1.71 (1.20)</b>	1.89 (1.43)	1.94 (1.49)
Product conservation time	3.59 (2.15)	<b>3.16 (2.00)</b>	3.32 (2.21)	3.43 (2.11)
Consistency of traceability system	2.35 (1.80)	1.84 (1.42)	<b>1.75 (1.47)</b>	2.14 (1.68)
Storage and delivery conditions	1.80 (1.17)	<b>1.55 (0.94)</b>	1.57 (1.01)	1.70 (1.09)

Quality of packaging	3.35 (2.43)	2.36 (2.05)	<b>1.84 (1.58)</b>	2.90 (2.32)
Firm's perception of its chain performance	2.41 (1.12)	<b>2.06 (0.81)</b>	2.24 (1.13)	2.28 (1.04)
Firm's perceptions of market opinion for its chain performance	2.34 (1.15)	<b>2.09 (0.90)</b>	2.24 (1.09)	2.25 (1.08)
Number of employees	4.18 (2.24)	20.51 (10.9)	86.49 (46.00)	18.73 (29.05)
*Turnover	5.81 (1.81)	6.71 (1.14)	6.68 (1.22)	6.22 (1.61)

\* 1: <20,000 €; 2: 20,000 - <50,000 €; 3: 50,000 - <100,000 €; 4: 100,000 - <200,000 €; 5: 200,000 - <500,000 €; 6: 500,000 - <1,000,000 €; 7: > 1,000,000 €

Specifically, micro firms outperform small and medium-sized firms only in terms of production / operational / raw material cost and profit margin. This can be explained by the simpler management structures employed by micro firms. It may be also due to the greater prevalence of owner-managers in micro firms compared to the greater prevalence of (non-owner) managing directors in small and medium-sized firms. The presence of owner managers creates a heightened level of loyalty from the local market, particularly with food micro retailers where there are frequent repeat customers and there is a high level of customer contact. These factors, in turn, have been observed to afford such firms the ability to command premium prices thus supporting higher profit margin. Finally, micro firms also have lower labour cost, especially if they are operating in rural areas. Medium-sized firms perform better in terms of delivery and distribution cost which may be due to the economies of scale enjoyed and they also perform better in the consistency of traceability system and quality of packaging. This may be explained by increased knowledge and skills possessed by the greater number of people working in these firms. Medium-sized firms tend to outsource their storage activities more than micro and small firms and this may help towards the reduction of their delivery and distribution cost. These medium-sized firms could also benefit by gaining expertise for packaging and traceability issues from the outsourcing providers. Small firms perform better in terms of the remaining measures. Specifically, they perform better for the four responsiveness and flexibility measures (see Table 7). Small firms also outperform in terms of product conservation time but the score of this measure is alarming (a mean score of 3.16 for small firms and a mean score of 3.43 for all firms suggesting slightly satisfactory). Therefore, product conservation time needs to be urgently improved. We need to stress that product conservation time is affected by the highly perishable nature of food products and this is reflected as a challenge for the SMEs operating in the food chain. Medium-sized firms serve larger markets and greater distances and this is also reflected in storage and distribution costs. Another interesting difference relates to storage and delivery conditions where small firms outperform micro and medium-sized firms. This may be due to high level of skills required especially for food products for deliveries and storage where a cold chain needs to be maintained throughout; conversely, micro firms underperform in this indicator.

## CONCLUSIONS, MANAGERIAL & POLICY IMPLICATIONS

Limited work has examined sustainability performance measurement in supply chains for SMEs (Gunther & Kaulich, 2005) and none, according to our knowledge, in relation to SMEs in the food supply chains. Based on the above, we believe that our work has addressed this gap in the performance measurement literature (Bititci *et al.*, 2012) by shedding light on the major sustainable performance differentials between all SME categories (micro, small and medium-sized firms) and by focusing at the same time on the same chain, the Greek food chain. Our work has generated many implications for managers and policy makers. For example, managers for micro firms need to be alert to the fact that their firms are underperforming in a range of measures and management action is required. Policy makers should also support these micro firms and identify ways to improve their sustainability performance especially when 9 out of 10 SMEs are micro firms at European and global levels (European Commission, 2005). One possible remedy



may be the use of e-business tools that can facilitate information exchange between chain members and could improve performance in terms of, *inter alia*, responsiveness and flexibility especially when SMEs tend to make limited use of these tools. A major managerial and policy implication of this work relates to product conservation time. Managers need to prioritise the development of sufficient infrastructure and policymakers should provide relevant incentives to SMEs to undertake appropriate improvements in this measure (and any other measures where there is scope for improvement). Overall, our work has highlighted a range of areas where improvement is required urgently and it will support managers of SMEs in terms of prioritisation of their resources which are limited for SMEs. Finally, a limitation of this work is that we made use of specific measures examining a specific sector in a given national setting (Greek food chain) and it precludes the generalisation of findings to other sectors and countries.

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# PRICE SETTING FOR FRESH AGRICULTURAL PRODUCT AT THE FARMER'S MARKET

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## ABSTRACT

Fresh agricultural products, i.e. vegetables and fruits, are originated in nature. Therefore, each of harvested product has own unique characteristics in size, weight, taste and etc. We have focused on the price setting problem for the product at farmers' market. And we have proposed price elasticity of demand based on shelf time in which identity of product is necessary to be assumed. In this paper, we have carried out interview and questionnaire survey on farmers to clarify their demand to the problem. According to the survey, we found that farmers face the price setting problem in an indirect way. And we also found that farmer's strategy much depends on business scale of him.

**Keywords:** Fresh Foods, Supply Chain Management, Decision Support System

## INTRODUCTION

Recently, Farmer's Market obtains much attention in Japan, where fresh agricultural products are traded between farmers and consumers. The market can be regarded to be a fresh food Supply Chain in which number of members is small. Therefore it is easier to analysis characteristics of fresh food. At the market, decision making on management, e.g. production, sales and inventory, is responsible of farmers. However, these are executed according to their experience and leaders opinion.

Fresh agricultural products, i.e. vegetables and fruits, are originated in nature. Therefore, each of harvested product has own unique characteristics in size, weight, taste and etc. This is important characteristics they are distinguished from industrial products that is iteratively produced according to certain design. As there are no identical product, meaning of counting sales amount is limited narrow than it of industrial products.

Takeo et al. (2012a, 2013) proposed idea of Price Elasticity of demand based on shelf time as an indicator for price setting problem. The indicator is expected to contribute to sell the products until it keeps freshness. Practical usefulness of indicator has not been discussed yet. This paper is companion of the Takeo et al. (2012a). In this paper, we have focused on attention of farmers on the price setting problem. Interview and questionnaire surveys are carried out for analysis on farmers' decision making process. Through the investigation, we clarify a part of the mechanism and methodologies for price setting at Farmers' market.

For this problem, we have established collaborated work foundation with a farmers' market as a case study target. Number of farmers registered and annual sales are about 100 members and 200M JPY respectively and that is categorized into the medium size market. The market and the production area are characterized with production of fruits, e.g. grapes and apples.

In Hanzawa et al. (2007), we proposed and implemented a sales and inventory management information system for fresh agricultural product at a farmers' market. In this system, e-mails were sent to farmers' cellular telephones, notifying them current sales tendencies of the need to replenish the stock presented for sale. Horikawa et al. (2009) regarded this replenishment mechanism as Vender Management Inventory (VMI) and described analyses of this data. Kasai et al. (2009) updated a database to identify 900 individual items and to record detailed information of sales and arrivals. Using the database, we can calculate the mean shelf time of the products from the period between arrival time and departure time for conditions of identical species, price and farmer. Ma et al. (2009) analysed sales records of the system and applied forecasting methodologies, such as the Box-Jenkins method, to the store. Shimokawara et al. (2011) extend information of the farmers' market to treat information about production planning.

### **PRICE ELASTICITY OF DEMAND BASED ON SHELF TIME**

Generally, the price of fresh agricultural products is determined at wholesale markets established by the national or local governments in Japan. For that reason, farmers in Japan have less opportunity to make their own decisions about price. However, in case of farmers' markets, farmers must determine the price and quantity of products to ship to the store by themselves. Stock shortages present a loss of opportunity. Alternatively, excess supply may occur according to farmers' decisions. Despite this, most farmers have insufficient information, experience and knowledge to perform these tasks because their core competency is farming.

Furthermore, fresh agricultural products differ individually leading to price differences. Here, we focus on shelf time for measurement of sales demand. Product freshness is an important advantageous point of farmers' markets. Some products are harvested within a couple of hours before their display in the store. To use that advantage, it is important to manage shelf time for the purpose of inventory control.

#### **Definition**

A suitable price is determined according to price elasticity to balance supply and demand (Soper 2004). However, every fresh agricultural product is different in size, condition of surface, taste and etc. It is therefore difficult to compare effects in prices of two products because they are not identical. Price elasticity cannot be applied to a product without some arrangements because elasticity is calculated according to the number of products sold. Here, we propose an alternative measurement of price elasticity of demand based on shelf time.

Suppose a product whose shelf arrival and departure time are  $A$  and  $D$ , respectively.

Shelf time  $T$  is defined as follows

$$T = D - A. \quad (1)$$

Here, departure time  $D$  corresponds to the time of purchase. If a product is attractive to

consumers owing to the price, then shelf time  $T$  is expected to be a low value. As  $T$  is an

ideal value, it is difficult to directly calculate it from practical data. In application,  $D$  can

be substituted with cashing time at Point of Sale (POS) terminals.  $T$  can be calculated

from the means of certain product groups. Then, we have

$$\text{Elasticity} = \frac{\text{Proportional change in shelf time}}{\text{Proportional change in price}} = \frac{\Delta T/T}{\Delta P/P} \quad (2)$$

Here,  $P$  represents the price. Note that the elasticity is a positive value because shelf

time is expected to be longer if price increases. Figure 1 presents the concept of price elasticity of demand based on shelf time. Horizontal and vertical axes show the sales price and shelf time at the store, respectively. The demand curve shows the relationship between the price and shelf time. At higher prices, the shelf time is longer because the consumer feels that the price is high. Conversely, at lower prices, the shelf time is shorter. The supply curve is also useful for farmers' decision-making especially for long-term decisions. However, it is difficult to adjust the amount of supply in the short term; the curve is regarded as a rather rigid line. The point at which the demand and the supply curves cross is theoretically the ideal price point.

### Application

We can calculate the shelf time at the store from point of arrival to the point of sales at a cashier. In application of price elasticity in farmers' markets, the lead time for supply, i.e. agricultural production, takes a much longer time than consumption does. Consequently, it is difficult to adjust the current supply according to the price elasticity of supply.

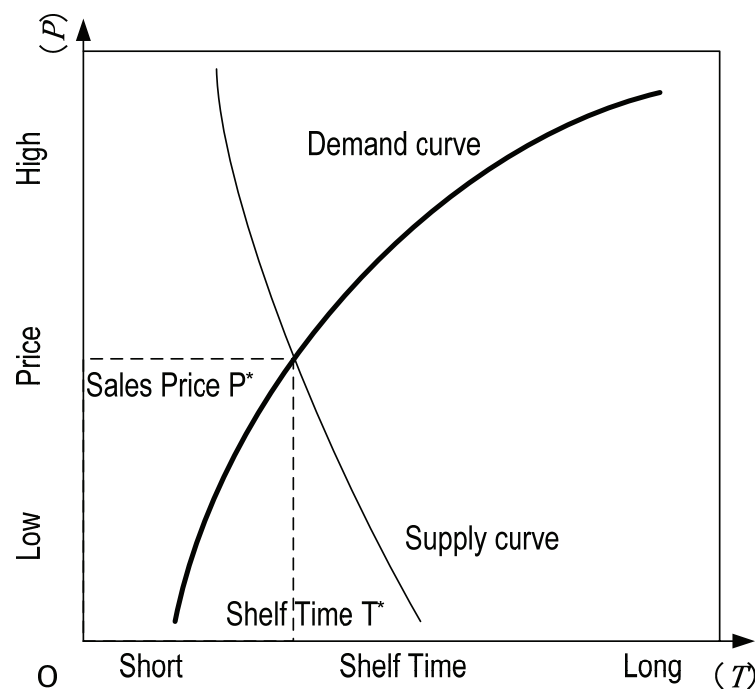


Fig. 1 Price elasticity of demand based on shelf time

### FARMER'S MARKET

Farmers' markets have become an important distribution channel in fresh agricultural products in Japan in the last two decades. Farmers sell their products directly to consumers at a store. Since the person who made the product might be readily known or identifiable, the products satisfy consumers' demands in regard to food safety. In Japan, such stores are called *Sanchoku*, which means direct sales at production areas.

Farmers' markets require the participation of customers, farmers and a manager who is a representative of farmers and the shop. Shelves inside the shop are assigned to farmers. Farmers prepare and manage their products on these shelves. Customers come to the shop and select some products from these shelves. They make payments to a cashier, as

in a supermarket, while farmers are able to work and spend time performing farming tasks. Occasionally, farmers visit the store to confirm the inventory. If the stock level dips below a certain level, farmers can replenish the products. After closing the store, the manager calculates the total sales for the day and informs each farmer of the total sales. Farmers must determine their own production, shipment, sales and other operation parameters. However, the core competency of farmers is agricultural production, especially medium-scale and small-scale farmers. Therefore, they have insufficient knowledge and methods to manage their businesses in farmers' markets. A certain amount of support for their store business is necessary to manage and run the store. Utilization of an information system can be a smart solution.

**Case Study of Akasawa Farmers' Market**

As a case study, our theory and information system has been evaluated at an existing farmers' market. The store is located in a suburb of Morioka city, a 30-min drive from the city centre. The store is established and managed by a farmers' cooperative union and the chair of the union is the management leader. There are approximately 130 registered farmers, i.e., 130 families. Annual sales at the store are approximately 200M JPY, implying that the management scale of the store is middle-sized. Most farmers run small businesses as retired workers. The store staff members consist of homemakers employed on a part-time basis. Most work as cashiers.

Figure 2 shows percentages of items in the 2008 annual sales. Main products are green vegetables, apples and grapes, where apples and grapes constitute over half of all sales. Figure 3 presents percentages of each month in the annual sales. Over 70% of sales are made during September–December: the high season of grapes and apples. At the store, problems of stock shortages and excess supply are more severe than at other farmers' markets. Solutions for this are anticipated.

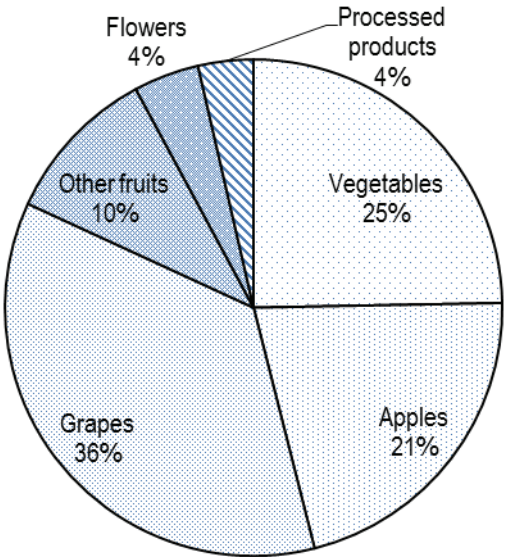


Figure 2 Main sale items by percentage of annual sales (2008).

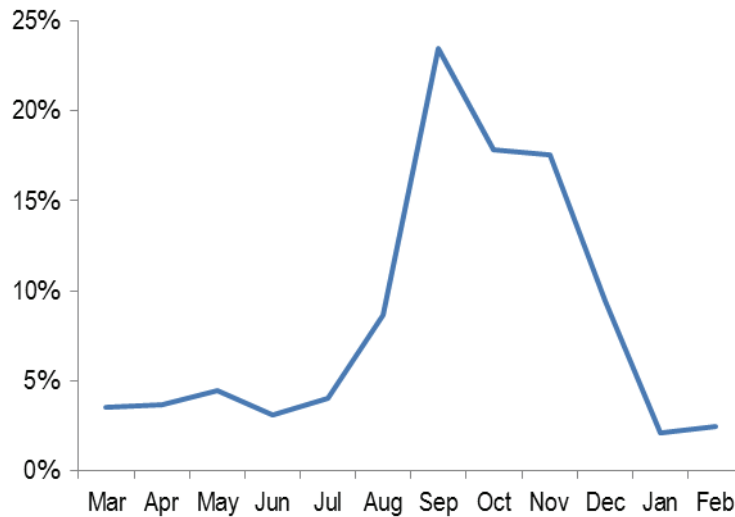


Figure 3 Monthly sales (2008).

### INTERVIEW AND QUESTIONNAIRE SURVEYS ON FARMERS

According to the elasticity of price based on shelf time, farmers can indicate suitable prices for their shipping product. To confirm availability of our proposal, we have carried out interview and questionnaire survey on farmers who belong to the Farmers’ market. At first, we create following research questions.

RQ1: Farmer faces problem in price setting at farmers’ market.

RQ2: Farmer demands decision support tool like price elasticity.

Following survey is carried out to clarify these research questions. RQ1 corresponds to a question to see severity in problems farmers face. RQ2 corresponds to a question to see that farmers are interesting to such tools. The survey consists of two stages: questionnaire survey and semi-structured interview. Questionnaire survey is carried out on following questions in late April 2013 at the farmers market.

From the investigation, farmers are divided into two groups, i.e. constant price setting type and fluctuating price setting type, according to Q1-1 and Q1-5. Production cost affects price however it is not weighted highly from Q1-3. Farmers rather satisfy their price setting methodologies, Q2-1 and Q3-5. However some farmers expect uniformed methodologies for price setting and the other is not. Most serious problem farmers think is determining package size, e.g. volume in a container. Interest on management tools is not high.

Table 1 Questionnaire survey to farmers (N=6) 5: strong applicable 1: not applicable

Id	Questionnaire	Mean	SD
Q1	Reference to decide price of your product. Suppose a product of which annual sales is the most if your way of decision depends on seed.		
Q1-1	Information sharing among farmers	3.17	1.83
Q1-2	Price at supermarket nearby	2.83	1.17
Q1-3	Production cost	3.33	0.52
Q1-4	Analysis on past sales data	4.00	0.89
Q1-5	Prices are set to be constant value	3.00	1.67
Q2	Impression about price setting derived from past sales data. Suppose a product of which annual sales is the most if your way of decision depends on seed.		
Q2-1	Well satisfying on price setting	3.17	1.17
Q2-2	Expecting personal price setting method or tool	3.00	1.26
Q2-3	Expecting uniform price setting method or tool	2.83	1.47
Q3	Facing management problems. Suppose a product of which annual sales is the most if your way of decision depends on seed.		

Q3-1	Selecting production items	3.17	0.98
Q3-2	Determining production amount	2.80	1.10
Q3-3	Determining package size	3.50	1.38
Q3-4	Determining starting time for selling	3.00	1.41
Q3-5	Price setting	2.67	1.03
Q4	Impression on management tools.		
Q4-1	Expected to be useful for management	2.67	1.37
Q4-2	Hating to lots of data entry	3.00	1.26
Q4-3	Participation of whole farmers belongs to the market	2.83	1.60
Q5	Other problems on management on farmers' market		
Q6	Largest shipping channel		
Q7	Main income source		

Interview survey is carried out on three farmers, referred A, B and C, who are occupied on leading position in farmer's union. A is a middle size farmer and his products are mainly shipped to the farmers market. B is a large size farmer and his products are mainly shipped to Japan Agricultural Cooperatives, i.e. national wide. C is a small farmer retired employee and he is earned by retired pension. Through the interview, following knowledge is obtained.

- B receives condition of markets including national wide however A and C are not.
- B changes the price often however A and C are not.
- A regards production cost however B and C are not.
- Prices of green vegetables are set to be lower than another market however fruits, e.g. grapes and apples, are not.
- C sets rather high price than another farmers.
- Development of value added products such as processed food, e.g. fresh juice, pickles, etc., are expected to avoid price fluctuation.
- Appearance of products is important to achieve high sales.
- As shipping volume becomes large in top season, escaping the season is also important management strategy.

## DISCUSSIONS

From the interviews, strategy of each farmer at farmers' market differs according to farmers and is much depended on production size and annual sales. Retired farmer, e.g. farmer C, puts more emphasis on profit from each package of product. On the other hand, large and middle sized farmers put more emphasis on amount of sales. Therefore larger farmer often changes the price to achieve high amount of sales. It is rational that larger farmer holds lots of inventory and risk according to the inventory. However, the risk of smaller farmer is little. These behaviours are seemed to obtain from their experience in farmers market. From the experience on customer behaviour, farmers are seemed to decide price at first. Then determine volume in a container. This is identical with the problem of price setting however they do not feel so.

Farmers belonging to the farmers' market do not seem to face management problem especially on price setting. However the problem of volume in a container is the same problem of price setting. The problem will come to the surface hereafter.

We have conclude the following for the Research Questions

A-RQ1: Farmers faces the price setting problem as a problem determining volume in a container.

A-RQ2: Strategies of farmers depend much on their scale of business. A decision support tool also has to consider the scale. Furthermore options are necessary to accommodate their needs.

## **CONCLUSION**

In this paper, we have pointed out the problem of price setting for fresh agricultural product and proposed an application of price elasticity of demand based on shelf time. We have carried out interview and questionnaire surveys on price setting problem at farmers' market. From the survey, we have found that farmer's behaviour and strategy much depends on their scale of production. Larger farmers aim on achieving high volume sales avoiding from inventory risk. On the other hand, smaller farmers aim on profit from each product rather than volume of sales. Therefore, to establish unified method for whole farmer in a farmers' market seems to be difficult. Furthermore, problem about attention of farmers is focused on achieving interest of consumers. In the near future, however, it is expected that the problem about price setting will be surface as their facing problem is inherently the same problem.

Classification of farmers in farmers market is our research subject. We are going to rebuild our theory for price setting problem to considering the farming scale. We are also extending the research target to more complicated supply chain model.

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# **MANAGING ON-SHELF AVAILABILITY OF GOODS – A CASE STUDY OF SUPERMARKET OPERATIONS IN SINGAPORE**

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## **INTRODUCTION**

On-shelf availability (OSA) of goods is a primary objective of retailers, who play a vital gate-keeping role in product supply chains. Maintaining OSA implies preventing out-of-stock (OOS) occurrences. It is a key performance indicator of retail logistics and is at the heart of order fulfilment management.

OOS inconveniences customers. According to Gruen and Corsten (2002), faced with an OOS situation, seven to 25 percent will choose not to purchase the item on that shopping trip, while 21 to 43 percent of consumers will shop elsewhere, depending on the product category. An earlier study of grocery shoppers in London by Schary and Christopher (1979) indicated that the proportion of customers electing to purchase an OOS item from another shop could be as high as 48%. In the fast-moving consumer industry, maintaining OSA has been referred to the “new battleground” in retailing (Corsten and Gruen, 2003: 603).

OOS is an extensively studied subject. Yet, despite 40 years of research, OOS rates remain at an average of 8.3% world-wide (Gruen and Corsten, 2002). Further, while there has been clear evidence that the store is the major contributor to OOS situations, the store continues to remain a ‘black-box’ in OOS research (Aastrup and Kotzab 2010). Previous studies on OSA tend to focus predominantly on issues such as consumer responses to OSA (Zinn and Lui 2001), influence of product assortment on OOS (Campo, Gijbrecchts and Nisol 2000), issues in managing OOS and OSA (Aastrup and Kotzab 2010), and use of technology to improve OSA (Raman, DeHoratius and Ton 2001). Relatively few studies have been directed to understanding the relationships between OSA and in-store operations, the “last 50 yards” of the supply chain (Fernie and Grant 2008: 293). This paper examines in-store processes for maintaining OSA to avoid or minimize OOS occurrences with a view to understanding how OSA could be cost-effectively managed.

## **LITERATURE REVIEW**

Extant literature defines OSA as situations in which an item is available for sales on shelf when a customer enters the store to purchase it (Chopra and Meindl 2007) and OOS occurrence as a situation when customers fail to locate the desired product in the store (Gruen and Corsten 2007). OSA, in short, is the inverse of OOS. It suggests effective distribution channel management where stocks are continuously available at the retail stores (Kucuk 2004) as well as good in-store practices that result in satisfactory customer service (Schary and Christopher 1979). Fernie and Grant (2008) added that OSA helps retailers enjoy store loyalty when customers experience reliable supply of stock on the display shelves. Grant et al. (2006) viewed OSA as a service level, which reflects the performance of “the last 50 yards” of a supply chain (Fernie and Grant 2008: 293).

A framework on consumer reaction to OOS developed, and tested, by Campo et al. (2000) indicates that consumers react to stock-outs in one of five ways: cancel purchase, defer purchase, switch store, switch package size, or switch item. Deferring purchase, switching package size or item may not hurt the retailer, cancelling purchase or switching

store would result in lost sales for the retailer. These are two of the negative consequences of failure to maintain OSA.

According to Aastrup and Kotzab (2010), who reviewed 40 years of OOS research since the Progressive Grocer (1968) study, OOS studies largely fall into two groups. The first concentrated on demand side issues and examined consumer responses to OOS. The second investigated supply side factors, focusing predominantly on the root causes of OOS and their extent with a view to reducing their occurrences. Little attempt has been made to integrate the two streams. Aastrup and Kotzab (2010) showed that the two streams can be integrated by adopting a differentiated approach to store ordering that focuses on balancing the costs of understocking against that of overstocking based on the importance of OSA for different product items, brands and categories.

Due to the importance of OSA on performance, research on OSA has largely been directed to exploring improvement methods. Corsten and Gruen (2003), for instance, suggested an integrated approach to spur performance in assortment planning, ordering systems, inventory control, store flow replenishment, and space allocation. ECR Europe (2003) recommended a combination of processes and approaches, which they termed seven levers, to improve OSA. Fernie and Grant (2008) also offered a conceptual framework to improve OSA by identifying the pre-requisites for the seven ECR Europe's (2003) levers. Empirical studies on how stores maintain OSA are few and far between. This study is an attempt to fill that void by looking at the interface between in-store operations and anticipated consumer reactions to OOS.

## **METHODOLOGY**

We employed an embedded case study approach to examine how individual stores of a supermarket chain in Singapore managed OSA. Studying the in-store practices of all stores from a single supermarket chain carries the advantage of having comparable chain-wide standard operations procedures and management policies, averting the worry of missing "unobservable across-unit heterogeneity" (Ton and Raman, 2010:550). Further, studying all stores of the same retail chain gave us the opportunity to contrast the subtle approaches taken by individual stores to meet the objectives and key performance criteria of the chain, affording a micro-level analysis of the nuances in OSA practices between the stores.

The selected case supermarket chain (referred to as Supermarket S in this study due to confidentiality reason) was one the key players in the Mass Grocery Retail industry in Singapore. At the time of our first contact with the management of Supermarket S in 2010, the chain was operating 23 stores on the island of Singapore. As we had no information on the known factors e.g., in-store processes (Kotzab and Teller 2005) or supply chain relationships (Ettouzani, Yates and Mena 2012) affecting OSA practices at the individual stores, we were not able to implement a purposive sampling to target particular stores. Consequently, we investigated all 23 stores for our study.

Of the 23 stores of Supermarket S, 16 were the standard single-storey neighbourhood stores, five were double-storey, one was a hypermarket and one was in a 3-storey structure. Variations in store sizes and set-up (i.e., single versus double versus three storey store front) among the 23 stores suggested that in-store displays and stock replenishment processes may differ due to dissimilar physical space constraints. These constraints offered us an opportunity to examine the effect of contextual differences on OSA management practices.

### **Data Collection**

We employed semi-structured interviews to understand the standard operation procedures involved in in-store operations, in particular inventory management, and on-

site guided tours of stores to capture in-store ordering, planning, receiving, and replenishment operations in action. Semi-structured interviews were conducted with store managers and supervisors at each of the 23 stores. All interviews were audio-recorded. Guided tours of stores were carried out either before or after the semi-structured interviews. Typically, the store manager together with one or, in some cases, two supervisors would conduct the store tour, explaining the what, how and why of each of the operations in process as well as the functions of each section visited and the associated activities that would take place there. The narratives of the guided tours were recorded. In addition, pictures of specific operations occurring within the store were taken.

**DATA ANALYSIS**

Data analysis comprised two phases: within case and cross-case. Within case analysis commenced with a scrutiny of the full range of stock-handling activities involved in retrieving an item from the backroom to displaying it on its intended location on the store shelf at each of the 23 stores. That scrutiny led to the creation of a coding scheme focussing on three areas of in-store operations carried out by each of the 23 stores: organizing and managing inventory in the backroom, top-shelves, aisles, and roller cages; planning, organizing and checking shelf display in store-front; and replenishing items on shelves. From the range of activities carried out under the three focus areas of in-store operations, four OSA management themes were identified: process management, product management, shelve management, and customer management. Table 1 presents the description, strategic intent and illustrative evidence of the four OSA management themes.

We then reviewed the strategic intent of the OSA management themes identified, contrasting them with the conceptual framework of consumer reaction to stock-outs developed by Campo *et al.* (2000). By triangulating data collected from the semi-structured interviews and on-site guided tours, we came out with six key OSA maintenance capability constructs: replenishment alert; back-front connectivity; purchase accessibility; substitution ready; and purchase support (Table 2). We then revisited the OSA maintenance practices of the 23 stores and compared them (cross-case analysis) against the five OSA management constructs to develop propositions for theory building.

**FINDINGS AND DISCUSSIONS**

The cross-case analysis suggests that the four OSA management approaches - process management, product management, shelve management and customer management – undertaken by the 23 Supermarket S’s stores were designed to deal with both potential, (i.e., when items began loosing their presence from display shelves) as well as actual (i.e., when items were absent from display shelves) OOS situations. The four OSA management approaches identified, as reflected by the range of varied activities individual stores routinely carried out, demonstrate that six strategic OSA management constructs were utilized to maintain OSA (Table 2), though not all 23 stores practised all six strategies. The deployment of the six OSA management strategies can be characterized as the building of a set of OSA maintenance capabilities to tackle OOS occurrences, whether potential or real, as depicted in Figure 1.

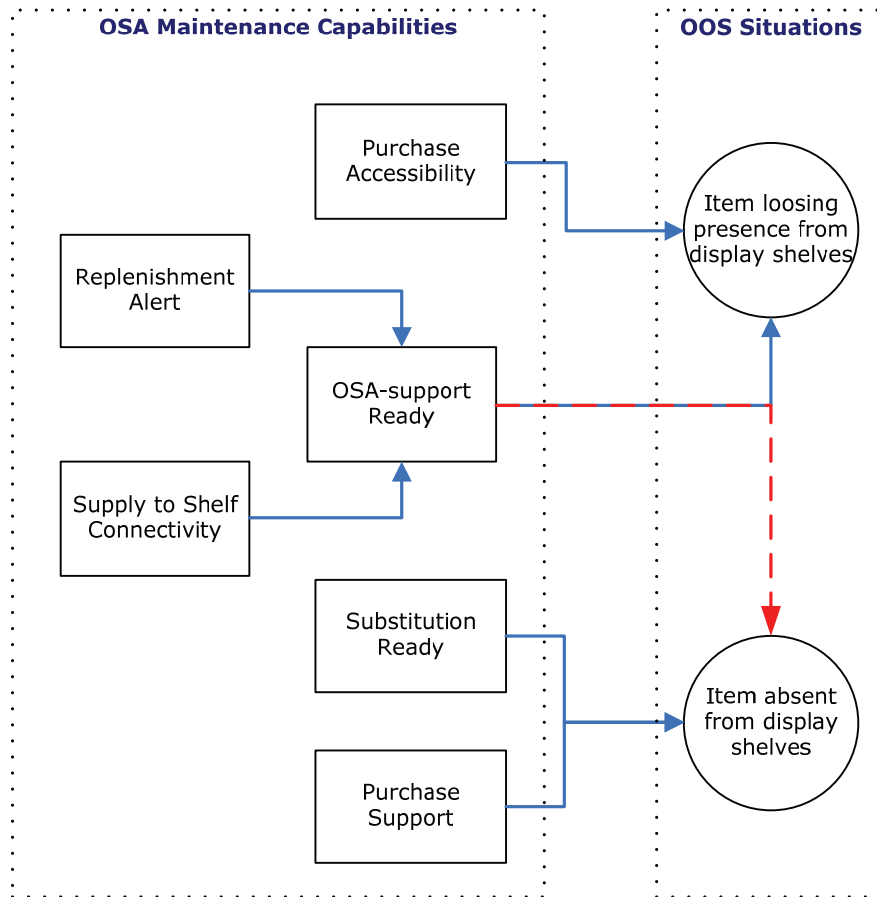
**Table 1: Description, Strategic Intent and Illustrative Evidence of Key OSA Management Themes**

Key OSA Management Approaches	Description	Strategic Intent	Illustrative Evidence
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<p>Process Management</p>	<ul style="list-style-type: none"> <li>• Checking and replenishing OOS items on display shelves at regular intervals to ensure product availability</li> <li>• Organizing back storage to ensure easy and fast shelf replenishment</li> <li>• Replacing price tags for OOS items with OOS tags to inform customers of product non-availability and to give priority to replenish OOS items at earliest possible time</li> </ul>	<ul style="list-style-type: none"> <li>• To ensure a seamless connection between display shelves and back storage</li> <li>• To minimize OOS occurrences at as short a time as possible</li> <li>• To inform customers that management was aware of non-availability of product items and actions had been taken to ensure product availability at earliest possible time</li> </ul>	<ul style="list-style-type: none"> <li>• Stackers went round stores multiple times a day to check for OOS products, replacing price tags with OOS tags as part of daily replenishment process.</li> <li>• Stocks organized and stored using a system designed according to the layout of the display shelves, the neighbourhood environment, and the set-up of the building (i.e., single versus two versus three storey buildings). Procedures developed were rigorously followed through with no tolerance for variation, except in unusual circumstances where store manager, in consultation with supervisor, would improvise an alternative, typically one-off, procedure.</li> </ul>
<p>Product Management</p>	<ul style="list-style-type: none"> <li>• Periodically going round store to check and collect misplaced items for re-shelving</li> <li>• Reducing price of a alternative brand should an item become OOS</li> <li>• Moving items at back of shelf to front when item in shelf front was already removed from shelf</li> </ul>	<ul style="list-style-type: none"> <li>• To ensure items were placed at the right location most of the time within stores</li> <li>• To entice customers to purchase an alternative brand when an item encountered an OOS situation</li> </ul>	<ul style="list-style-type: none"> <li>• Instructing employees to routinely go through shelves to collect misplaced items for re-shelving.</li> <li>• Actively sought feedback about product assortment preferred by customers.</li> <li>• Deliberately stocking special range of food and non-food items at very low-priced to cater to a special group of customers (construction workers living in a dormitory next to store) and also lowering price of competing brands if item became OOS.</li> </ul>
<p>Shelf Management</p>	<ul style="list-style-type: none"> <li>• Strategically placing products (e.g., shampoos or hair dye) of similar size (e.g., 250 ml bottles) but different brands next to each another</li> </ul>	<ul style="list-style-type: none"> <li>• To ensure customers had the choice of a substitute brand should an item become OOS</li> </ul>	<ul style="list-style-type: none"> <li>• Shelf stacking personally trained by store manager.</li> <li>• Set as a rule to neatly stacked, display shelves to the full and according to display labels.</li> <li>• Aligning shelved items with edge for easy retrieval by customers.</li> </ul>
<p>Customer Management</p>	<ul style="list-style-type: none"> <li>• Assisting customers to locate an OOS item</li> <li>• Replenishing an OOS item in immediate response to customer enquiry</li> <li>• Promoting alternative brands of OOS products to customers</li> </ul>	<ul style="list-style-type: none"> <li>• To minimize customer dissatisfaction when an item was in an impending OOS situation</li> <li>• To reduce chances of customers deflecting to competitor to obtain OOS items</li> </ul>	<ul style="list-style-type: none"> <li>• Coaching employees to actively assist customers to locate OOS products via physical checks and 2-way communications to get stackers to join in search for item(s). Extra helpful for elderly customers.</li> <li>• Encouraging employees to actively promote alternative brands to customers and to educate elderly customers on new products or new brands</li> </ul>

**Table 2: OSA Maintenance Capabilities**

<b>OSA Maintenance Capability</b>	<b>Description</b>	<b>OSA Management Approach</b>	<b>Illustrative Evidence<sup>1</sup></b>
Replenishment Alert	Dedicated efforts made to spot location of impending OOS occurrences at store	<ul style="list-style-type: none"> <li>• Process Management</li> </ul>	<ul style="list-style-type: none"> <li>• Stackers were asked to monitor stock level and on-shelf availability as part of their routine replenishment task (23)</li> <li>• Store managers and supervisors performed visual checks on display shelves during routine walkabout (23)</li> </ul>
Supply to Shelf Connectivity	Ability to speedily locate and move stock from back storage, unloading bay, roller cage and top shelf to display shelves to prevent or salvage an OOS situation	<ul style="list-style-type: none"> <li>• Process Management</li> </ul>	<ul style="list-style-type: none"> <li>• Stackers followed a well-defined, prescribed process to store and display items depending on sources of supplies (23)</li> </ul>
OSA-Support Ready	Capability to respond to and rectify OOS situations at short notice	<ul style="list-style-type: none"> <li>• Process Management</li> </ul>	<ul style="list-style-type: none"> <li>• Stores were able to rectify OOS items within the same day during normal supply situation (23)</li> </ul>
Purchase Accessibility	Effort rendered to make an item visible and accessible for purchase	<ul style="list-style-type: none"> <li>• Product Management</li> </ul>	<ul style="list-style-type: none"> <li>• Stackers were instructed to place all shelved items (i.e., including items not being replenished) to align with edge of display shelves as part of replenishment process (14)</li> </ul>
Substitution Ready	Capability to minimize the chance of a lost sale by having one or more substitute item(s) ready for customer consideration	<ul style="list-style-type: none"> <li>• Product Management</li> <li>• Shelve Management</li> </ul>	<ul style="list-style-type: none"> <li>• Store managers instructed stackers to rearrange shelves with OOS items to increase visibility of competitor brands, including re-pricing to promote competitor brands as substitute items (18)</li> </ul>
Purchase Support	Capability to quickly come to aid of customer facing an OOS situation	<ul style="list-style-type: none"> <li>• Customer Management</li> </ul>	<ul style="list-style-type: none"> <li>• All employees were coached to proactively assist "display-unfamiliar" customers to retrieve OOS items (23)</li> </ul>



**Figure 1: A Model of OSA Maintenance Practices**

The OSA practices at the 23 Supermarket S's stores indicate that having standard operation procedures in place to nurture the capabilities of "replenishment alert" and "supply to shelf connectivity" is a fundamental requirement to becoming "OSA-support ready", which we define as the ability to respond, at short notice, both to impending OOS situations and to rectify OOS occurrences. Due to dissimilar physical space constraints between the 23 stores, individual stores used a combination of three distinctive order receiving-storage-shelving processes to manage ambient product (i.e., non-chilled) items, depending on the supply sources, i.e., whether from Supermarket S Warehouse or from individual suppliers. Despite the relatively complex procedures involved stemming from space availability in different cases, all the processes were well defined, with stackers trained to follow a very rigid, prescribed routine. Deviation was not tolerated. This practice led to a seamless supply to shelf connectivity, a critical capability to ensure the flow of goods between supplies, storage, store front and display shelves in "the last 50 yards", in Grant and Fernie's (2008) terminology.

The second set of procedures to develop the OSA-support ready capability is a culture of monitoring stock level and on-shelf availability throughout the day. The experience of Supermarket S's stores suggests that this process could be cost-efficiently executed in two ways. The first is to incorporate this task as an expected responsibility of stackers in their routine replenishment function, as carried out in all 23 of Supermarket S's stores. The second is to institute a practice to have store managers and supervisors performed visual checks on display shelves, addressing potential OOS situations on-the-spot or noting OOS occurrences, during their routine walkabout.

The cross-case findings also reveal that “purchase accessibility” was a simple, yet effective, way to prevent a potential OOS situation from occurring. Purchase accessibility represents efforts rendered to make an item visible and accessible for purchase. Fourteen of the Supermarket S’s stores required their stackers to arranging all shelved items (i.e., including items not being replenished) to align with edge of display shelves during their routine item replenishment process. In the words of one of these 14 store managers, “many of the aunties (*elderly female shoppers*) were not tall enough to reach the higher shelves or see items tucked inside the higher shelves. Bringing all items to the edge of the display shelves, especially those placed on higher shelves, would make our products visible and accessible for purchase by all customers”.

To deal with items where OOS already occurred, the practice employed by the 23 stores indicate two relatively effective means of averting a lost sale. The two means are labelled as “substitution ready” and “purchase support” capabilities. We define substitution ready as a capability to minimize the chance of a lost sale by having one or more substitute item(s) ready for customer consideration. Our case study of Supermarket S shows that 18 of the store managers instructed their employees to rearrange shelves with OOS items to increase the display of competitor brands. In most instances, the price of the competitor brands was reduced to promote their sales.

Purchase support is a practice where employees, especially stackers, were coached to take proactive steps to assist customers who appeared to be facing difficulties locating specific items not visible on display shelves. Our on-site tours revealed that many of the stackers and supervisors went out of their duty station to assist the “display-unfamiliar” customers to retrieve those items. Failing which, they often made an effort to offer an alternative brand or size model as a substitute. Such promotional attempts did work at times, especially when the employee introducing the substitute items had a sound knowledge of the product.

## **IMPLICATIONS AND CONCLUSION**

The findings from our case study of Supermarket S showed that maintaining OSA requires 1) a disciplined approach to managing the stock receiving-storing-shelving process to build a seamless supply-to-shelf connectivity capability, and 2) a culture of monitoring stock level and on-shelf availability throughout the day to become replenishment alert. These two capabilities - supply-to-shelf connectivity and replenishment alert - are prerequisites to developing an OSA-support ready capability, which are fundamental to maintaining OSA.

In addition, our findings also indicated that purchase accessibility, i.e., making items visible and accessible for purchase, could avert potential OOS occurrences. It was a matter of establishing a habit of arranging all shelved items to align with the edge of display shelves during routine replenishment process.

In situations where OOS already occurred, our case findings indicated that it was not necessary a case of lost sale, if retailers had a substitution ready strategy in place. Equally, a strategy of purchase support could also sometimes turn what apparently appears to be a lost sale into a satisfied purchase to the customer. The trick lies in coaching employees to be proactive and helpful - go the extra step to educate the shopper of the value of the substitute item.

These findings carry significant implications, both for theory building as well as for developing best OSA management practices. Examining the interface between store operations and consumer behaviour encountering an OOS situation, this study has shed light on what appears, at the present stage, a black-box operation. Understanding how supermarket stores maintain their OSA through a combination of strategies and capability development, this study has opened a new avenue to study OSA management,

as a response to the call of Aastrup and Kotzab (2010) to explore means of optimizing OSA rather than minimizing OOS.

From a practice point of view, findings from this study have indicated that OSA is not an untameable beast. Managing OSA requires a culture of disciplined practices to be implemented in a highly orchestrated manner.

## **LIMITATIONS AND FURTHER STUDIES**

As with all case studies, the findings cannot be readily generalized to other contexts or industries. The context in which the study was conducted came from a setting with a highly disciplined culture of work practices and distinctive consumption behaviour. The OSA maintenance constructs identified could thus be situation specific. Further investigations to validate the OSA practices unearthed in this study will be a logical extension, which will add to grow the pool of empirical research on OSA management.

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# TRENDS AND CHALLENGES IN MANAGING DAILY CONSUMER GOODS SUPPLY CHAINS

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## ABSTRACT

Future trends in the retail and business environment, such as increasing complexity, increasing competition, new consumer shopping behaviours, retailer coordinated value chains and sustainability approaches require new models for managing consumer goods supply chains. New types of efficient and responsive coordinated logistics networks are needed to support changing customer demands and to take account of the various quality parameters, organizational conditions and requirements of market segments. The objectives of this study were as follows: (1) to identify the most significant trends affecting daily consumer goods supply chains; (2) to identify the opportunities and challenges facing the daily consumer goods logistics companies; and (3) to consider the success factors in managing tomorrow's daily consumer goods supply chains.

## 1. INTRODUCTION

The continuous flux in the retail and business environment is characterized not only by complexity, but also by uncertainty, which brings challenges for supply chain management. Especially in recent years, various disruptions have become more common in supply chains due to increasing supply chain complexity. Future trends, such as increasing competition, new consumer shopping behaviours, retailer coordinated value chains, green values and sustainability approaches require new models for managing consumer goods supply chains (Zentes & Rittinger 2009, Dawson 2010, Trienekens et al. 2011). For example the food sector, which is the largest economic sector in the European Union, consists of a complex, global and dynamically changing network of trade streams, food supply network relations and related product flows (Fritz & Schiefer 2008). New types of efficient and responsive coordinated logistics networks are needed to support changing customer demands and to take account of the various quality parameters, organizational conditions and requirements of market segments. The purpose of this paper is to identify the most significant trends, opportunities and challenges facing the daily consumer goods logistics companies. The paper also aims to explore the case company's development possibilities in supply chain management and to consider the success factors in managing tomorrow's daily consumer goods supply chains.

## 2. METHODOLOGY

The paper is based on an empirical inquiry in the form of workshop and a literature review of the context of daily consumer goods supply chains. In the literature review we examined the current state of logistics management, future trends and challenges in the daily consumer goods industry. For a systematic literature review, we agreed on a set of keywords describing the phenomenon under study from several different angles. We then used these keywords to search for relevant studies.

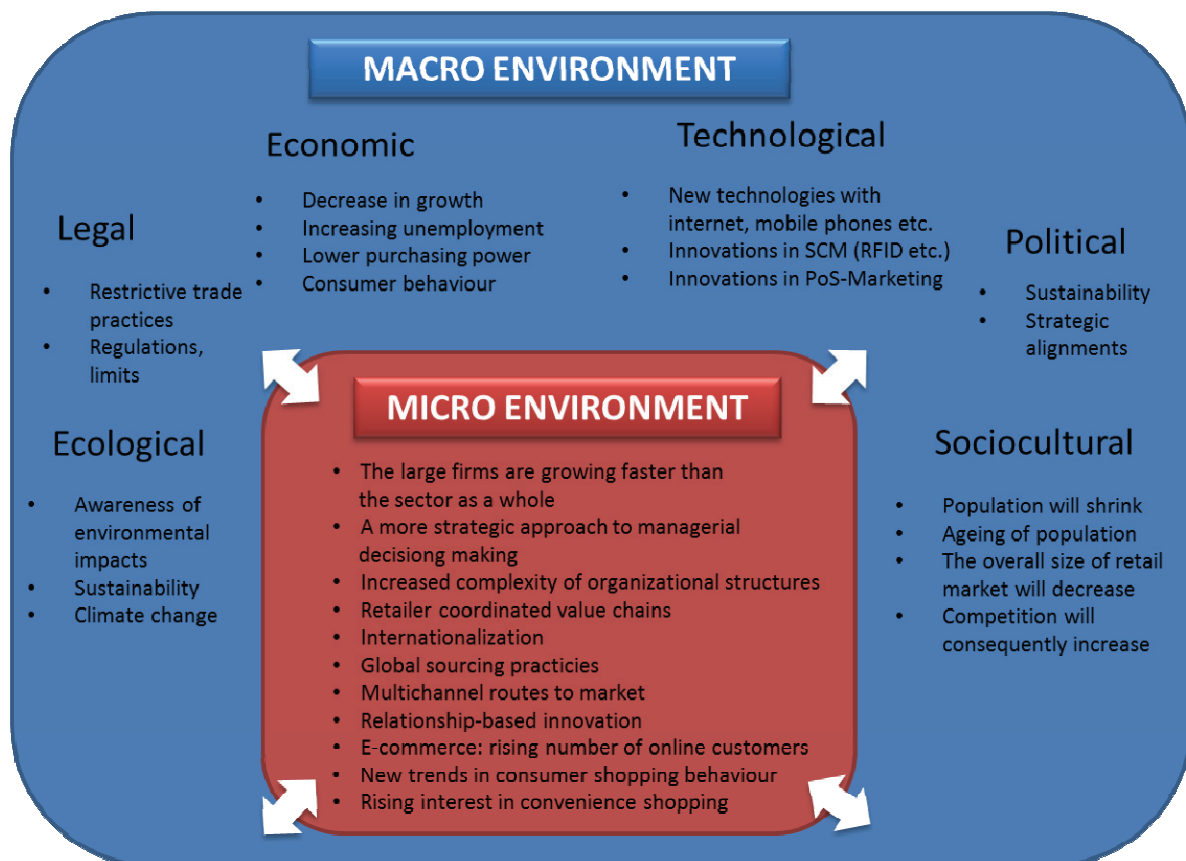
The workshop, the results of which are described in this paper, was organized in autumn 2012 in Finland. Workshops are among the participatory research methods used to facilitate group processes to deal with actual problems concerning the group (Vidal 2006). Participatory methods are more likely to produce normative than analytic results, i.e. they can be used to produce general strategies rather than specific plans (Glenn 2009). Fifteen experts and managers of a Finnish daily consumer goods logistics company attended the workshop and gave their opinions through individual assessments, group discussions and voting. During the first part of the workshop, the future trends in retail were classified in a scale of significance. After classification, experts were asked to consider the opportunities and challenges of these trends in their supply chain management development. In the second part of the workshop, the development

possibilities in logistics operations and supply chains were discussed. The success factors in managing daily consumer goods supply chains were also considered.

Based on the literature review and the workshop, the paper achieves the following three objectives: (1) identifies the most significant trends affecting daily consumer goods supply chains; (2) identifies the opportunities and challenges facing the daily consumer goods logistics companies; and (3) considers the success factors in managing tomorrow's daily consumer goods supply chain.

### 3. TRENDS IN THE DAILY CONSUMER GOODS SECTOR

Future trends in the daily consumer goods sector can be examined with two different approaches: a macro environment and a micro environment. A macro environment consists of the future trends in the political, economic, social, technological, ecological and legal environment. A micro environment includes trends related to, for example, buyers, substitutes and new technology, and general business trends (Zentes & Rittinger 2009).



Picture 1. Classification of the future trends in the daily consumer goods sector.

Upon closer examination of the business trends in the micro environment, the retail trends in Europe indicate that the role of large firms is likely to be strengthened and that these firms are growing faster than the sector as a whole. This also includes a more strategic approach to managerial decision-making, which means that a general business strategy is made operational through functional strategies for marketing, merchandising, buying, branding, logistics, employees, finance etc. (Dawson 2010). Moreover, the increased size of firms leads to the increasing complexity of organizational structures (Dawson 2010, Trienekens et al. 2011).

On the other hand, retailers have become increasingly involved in coordinating the relationships between retailers and suppliers (Dawson 2010) and the retail business is

moving towards retailer-coordinated value chains (Ganesan et al. 2009, Dawson 2010). These changes increase the concentration of markets and shift the focus to larger retail units instead of small and micro firms. This may to some extent change the balance of competitive power between retailers and their suppliers. The international activity of retailers is likewise predicted to increase (Dawson 2010).

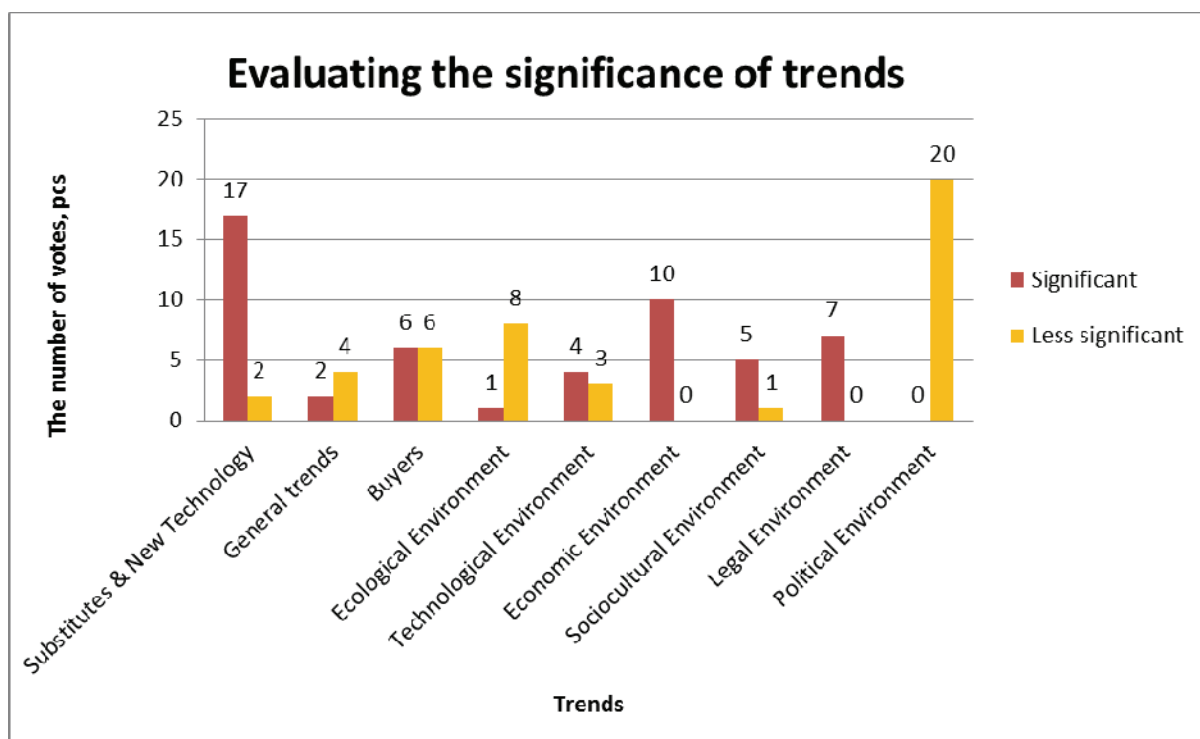
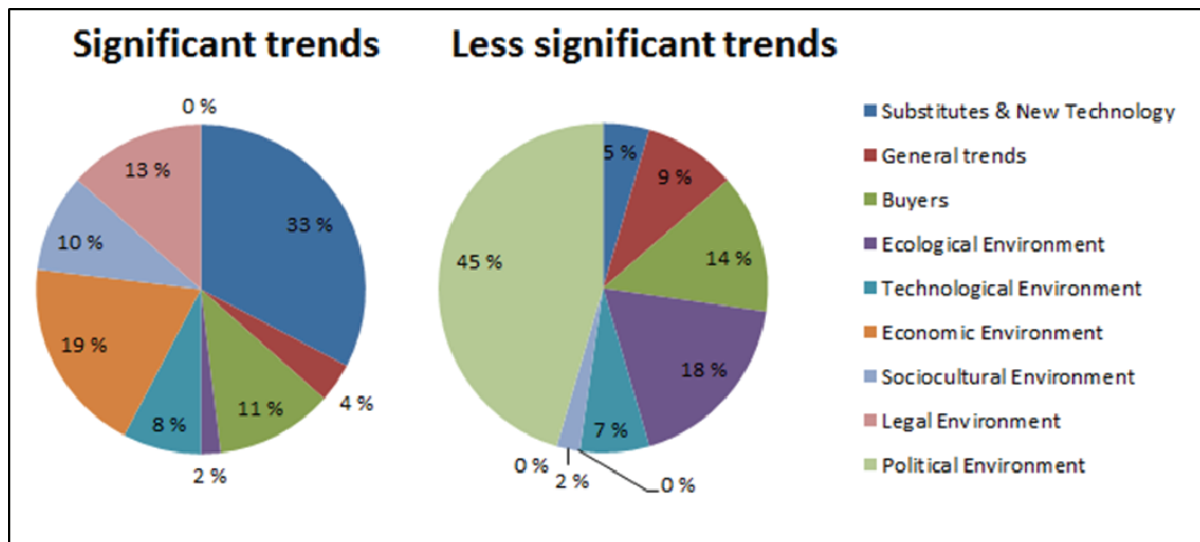
According to Zentes and Rittinger (2009), technological innovations in supply chain management are one major part of the future development in the retail sector of daily consumer goods. Utilization of Radio Frequency Identification (RFID) technology is one approach in making logistics operations more effective and transparent since the management and leadership of supply chains for daily consumer goods are based on information. Another approach related to technological innovations is e-commerce solutions in the business-to-consumers (B2C) trade. Business-to-business (B2B) solutions are used effectively in B2B operations, but the consumer trade requires new solutions for the deliveries of daily consumer goods. The number of online customers, however, is steadily increasing, ensuring that online retailing will become a natural part of retailing. Trends in consumer shopping behaviour include new needs, an increasing quality orientation and a growing interest in convenience shopping (Zentes & Rittinger 2009). We can say that retail is becoming faster, more digital and heavily influenced by shoppers as social and mobile technologies and media take root in society. Stores are becoming smaller, and arguably less relevant, as e-commerce tightens its grip on the future of retail (Berg & Bryan 2012).

#### **4. EVALUATING THE SIGNIFICANCE OF TRENDS**

In the first part of the workshop, the retail trends were classified in a scale of significance in the light of daily consumer goods logistics. The evaluation process was conducted through voting. Each participant received five red stickers and five yellow stickers. The red stickers represented the significant value and the yellow stickers represented the less significant value. The significant trends should be taken into account in future actions, plans and operations in logistics, whereas less significant trends do not require a direct response. The participants were asked to vote which trends and challenges are the most significant and which are the least significant. The idea was to vote on at least three different subjects per colour. Both macro and micro environment trends and challenges were taken into account. Macro environment trends were divided into the following themes: political, economic, social, technological, ecological and legal environment. Micro environment trends were divided into the following themes: buyers, substitutes and new technology, and general trends.

According to the workshop participants, the most significant trends are in the substitutes and new technology category, meaning e-commerce, the development of new technologies with the internet, mobile phones and other future innovations, and the development and growth of multichannel strategies. This category received 33 % of the votes. The second largest category was the economic environment, which received 19 % of the votes. This category included the following trends: the decrease in growth, increasing unemployment, lower purchasing power, increasing uncertainty across society and customers' will to save more and consume less. The third significant category features trends that are related to the legal environment, including restrictive trade practices, regulations and limits (13 %).

Trends related to the political environment were considered to be the least significant with 45 % of the votes, followed by ecological trends (18 %) and then trends related to buyers (14 %). The rising interest in convenience shopping was recognized as the most significant buyer-related trend. The political environment consists of sustainability and strategic alignment trends. The ecological environmental consists of trends like awareness of environmental impacts, sustainability and climate change.



Picture 2. Significance of trends for the development of daily consumer goods logistics.

## 5. OPPORTUNITIES AND CHALLENGES IN MANAGING DAILY CONSUMER GOODS SUPPLY CHAINS

After classification, experts were asked to consider the opportunities and challenges related to the three most significant trends (identified during the workshop) with respect to their supply chain management development. The three most significant trend categories to be considered here were: substitutes and new technology, economic environment and legal environment.

### Substitutes and new technology

One of the opportunities that can be actualized by using new technology is improvement of the efficiency in supply chain operations. Until now, technological innovations have enabled the development of faster and longer supply chains due to our ability to track goods in production, storage or transit. The application of newer technologies (such as

RFID) and wider adoption of electronic commerce will strengthen a company's competence in logistics.

Experts also highlighted the importance of transparency in supply chains and utilization of real-time data. There is great potential to improve the information flow in supply chains as well as opportunities to improve efficiency through real-time data utilization. On the other hand, having lots of information available was also seen as a threat, especially if there is too much information or if the information is misinterpreted. Finding the most suitable new technologies is challenging; though there is always a risk in being a pioneer, without taking risks in implementing new technologies the company can easily lose its competitive advantage. Product volume fragmentation was also perceived as one of the challenges because it will lead to an increase in costs.

### Economic environment

The economic environment refers to the nature and direction of the economy in which companies compete. The experts in the workshop saw a poor economic environment as an opportunity to acquire new employees for their business, particularly when there are high unemployment rates. In a poor economic environment, the company should try to increase growth and overcome growth weaknesses. The challenge, however, is that logistics costs may increase due to the poor economic situation because the entire logistics system is based on economies of scale. The poor economic situation can also influence delivery methods; for example, as a result of changes in packaging or packaging technology. Smaller delivery sets can also lead to changes in delivery frequencies.

### Legal environment

Generally, all restrictive trade practices, regulations and limits will challenge everyday business. On the other hand, quality in logistics operations can be improved through regulations (for example, regulations related to transport equipment). The coming regulation regarding several temperature classes was perceived as a challenge by the experts in the workshop as it will result in more transports and have an impact on for example fish deliveries.

Table 1. Opportunities and challenges of the trends in daily consumer goods supply chains.

Trends	Substitutes & new technology	Economic environment	Legal environment
<b>Opportunities</b>	<ul style="list-style-type: none"> <li>Improvement of efficiency in supply chain operations</li> <li>Transparency in supply chains</li> <li>Better utilization of real-data</li> </ul>	<ul style="list-style-type: none"> <li>New employees</li> <li>Increase the growth</li> </ul>	<ul style="list-style-type: none"> <li>Higher quality in logistics operations</li> <li>competitors</li> </ul>
<b>Challenges / Threats</b>	<ul style="list-style-type: none"> <li>Too much information</li> <li>Data misinterpretation</li> <li>Finding right and suitable technologies, threat of pioneer</li> <li>Product volume fragmentation, increase in costs</li> </ul>	<ul style="list-style-type: none"> <li>Increasing logistics costs</li> <li>Logistics system based on economies of scale</li> <li>Delivery methods, packaging technology</li> <li>Smaller delivery sets, changes in delivery frequencies</li> </ul>	<ul style="list-style-type: none"> <li>Restrictive trade practices</li> <li>Regulations, limits</li> <li>Several temperature classes, more transports, impact on fish deliveries</li> </ul>

## 6. DEVELOPING THE DAILY CONSUMER GOODS SUPPLY CHAIN MANAGEMENT

One of the important elements in daily consumer goods companies' strategy is value-focused thinking and creating value for customers (Hemphill 2005, Al-Mudimigh et al.

2004). Success stories in daily consumer goods companies also highlight the importance of a particular distribution strategy called cross-docking (Fernie & Sparks 2004, Grant 2012). Utilization of the available information technology enables better information sharing, more efficient logistic processes, faster response to customer demands and optimized communication and cooperation with suppliers. Technological innovations can be said to be one major part of the future development in the daily consumer goods sector. E-commerce is also becoming more important in both B2B and B2C operations. Service and delivery options play an important role as customer demands vary over time. (Fritz et al. 2004, Chaffey 2007)

Improving supplier cooperation and relationships is mostly connected to information technology development. Sustainability and green logistics issues are becoming more important to increase interest in energy efficiency improvements. This can be seen in carbon footprint calculations for the products, willingness to ascertain and reduce environmental impacts and setting specific criteria for suppliers (Berg & Bryan 2012, Carrefour 2012, Grant 2012, Metro Group 2012). It is clear that just-in-time deliveries, cost-efficiency, quality, accuracy and availability of products in grocery stores are essential success factors in the daily consumer goods business. It also has to be taken into account that different customer segments may have different expectations and demands. The main challenge is to combine cost-efficiency, high turnover rate, customer driven approaches, fast response to increasing customer needs through high service level and especially strict regulations related to the characteristics of daily consumer goods.

The success in daily consumer goods companies, from the supply chain point of view, seems to relate to the following themes: strategy, distribution strategy and network, e-commerce, information technology, supplier cooperation and relationships, and sustainability. In the second part of the workshop these themes were discussed in the light of developing the case company's supply chain management. The participants were asked to consider the development possibilities with respect to making the company's supply chains more efficient and cost effective. The results of the workshop are discussed below.

### **Strategy, distribution strategy and distribution network**

The logistics approach should be involved in the case company's strategy to ensure that both logistics and supply chain management are perceived as one of the key elements in the company's success. As a result of the workshop discussion, it is clear that there is also a need to develop the operation management and to ensure total control of the processes and supply chain integration. More management information is also needed. One of the key findings with respect to ensuring optimal control of the deliveries is the corrugation development for both inbound and outbound deliveries. For freight transports, more regular schedule windows could be implemented to make receiving freights easier. One of the aims should also be to increase the turnover rate in storage and terminals.

Deliveries to the stores could be done in different waves depending on the product. For example, frozen and ambient grocery products could be delivered in the following three waves: the first wave could be delivered to the stores by 8:00 am, the second wave in the afternoon and the third wave in the evening. Tesco is an example of a company using this approach with its deliveries. There is also a lot of potential to develop the tracking of the material flow and goods by implementing new technology. By doing so, more management information would be available. With respect to the distribution network, the terminal network should be re-examined.

### **E-commerce and information technology**

According to the experts and managers in the workshop, information management is one of the key elements in supply chain management. One concrete practice which could be applied to improve the delivery service is e-commerce pick-up delivery. Generally, there

is a need to improve information sharing throughout the whole supply chain. This need is especially great with respect to the volume and amount of products. Accelerating the flow of information is also one of the goals shared by the experts. Orders with the suppliers could be placed by means of electronic data interchange. More efficient communication with respect to trading information was seen as another future development goal.

### **Supplier collaboration and relationships**

During the workshop, the experts emphasized the importance of vertical collaboration through information sharing, electronic trading and collaborative improvements with suppliers. There are many emerging possibilities in this regard, including, for example, integrated information technology (IT) with suppliers in the form of electronic data interchange (EDI). Best practices could be learned from companies such as Tesco and Wal-Mart with the aim of further optimizing the communication and cooperation with the suppliers. In addition to the delivery site, the procurement site could also incorporate the practice of receiving deliveries in different waves. There is also a need for better scheduling in procurement. New forecasting operation models are currently under construction.

### **Sustainability**

Development of both reporting and measuring in the supply chain management were viewed as two of the most important things that could help improve the realms of green logistics and social responsibility. The need for new approaches and new parameters was also recognized. The company should study the details regarding their own energy consumption, CO<sup>2</sup> emissions and transportation costs. Environmental reports and calculations should be utilized in logistics operations development. One mentioned example was supplier packaging scorecard that formally rates suppliers on their progress towards developing sustainable packaging. This kind of scorecard is used by Wal-Mart.

## **7. CONCLUSIONS**

According to the results of the workshop, one of the most significant trends affecting daily consumer goods supply chain management seems to be the development of new technologies. These technological developments enable more efficient logistics, information transparency and operational real-time information to plan and control supply chain operations precisely. Underlying the success of larger daily consumer goods companies like Wal-Mart and Tesco is the strong will and courage to develop and implement new technology innovations in order to improve the efficiency of the supply chains. Wal-Mart and Tesco have been both pioneers in this area and have achieved good results with their business solutions. At the same time, it seems that these companies are far ahead of even the average large consumer goods companies, which have not seen the technological development that important for improving logistics efficiency. This way also the case company considered in this paper, which in Finland is a significant player in daily consumer goods industry, was representing the idea not to be the pioneer in all new technology innovations, but rather use their own operation models and then follow the leader ones.

The second significant trends affecting supply chains were considered to be the trends related to the economic environment followed by the trends related to legal environment, including restrictive trade practices and regulations and limits. The most prominent success factors among the daily consumer goods companies studied can be divided into the following categories: strategy, distribution strategy and network, information technology, e-commerce, supplier collaboration, relationships and sustainability. The experts in the workshop strongly emphasized the importance of distribution strategies, network solutions and development possibilities. Furthermore, they also stressed the importance of strengthening information sharing throughout the whole supply chain for future development. With respect to supplier collaboration and relationships, vertical collaboration with information sharing, electronic trading and collaborative improvements

with suppliers should be developed in the future. The need for new approaches and measures for green supply chain management and social responsibility were also recognized.

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# THE EFFECTIVENESS OF A RETURN POLICY IN A DECENTRALIZED SUPPLY CHAIN UNDER RETAIL COMPETITION

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## ABSTRACT

We study the effectiveness of a return policy as an incentive compatible mechanism in a two-stage supply chain under retail competition with uncertain demand and short selling season. Supply chain performance with regards to profitability and service level as well as the stakeholder dynamics is studied when coordination is implemented to maximize potential system throughput while enabling risk hedging at the retailer level. Analytical model used to capture characteristics of coordinated return policy for items with short selling seasons is based on Pasternack (1985). Numerical experiments are conducted via simulations to evaluate the joint effects of competition and coordination through a return policy under four different settings: (I) no coordination without competition, (II) coordination without competition, (III) no coordination with competition, and (IV) coordination with competition. Results indicate that retailer heterogeneity and demand variability exert significant impact on supply chain performance measures. The primary contribution of this paper lies in providing insights into the effectiveness of a coordination mechanism and identifying settings under which coordination and competition could improve supply chain performance.

**Keywords:** decentralized supply chain; coordination; retailer competition; return policy; simulation

## 1. INTRODUCTION

One of the most apparent industry trends observed since the late 20<sup>th</sup> century is time-based competition. The speed and quantity of business transactions made both online and offline require that companies focus on a new dimension of competitive priorities, time, to respond to changes in the external marketplace (Stalk & Hout, 1990). Short product life cycles common in high clockspeed industries along with the need to reduce product development time create significant supply chain management problems (Akkermans, Bertrand, & Verhaegh, 2000). Coordinating both time and timing of product delivery to the marketplace has become a mandate for every business competing in a complicated global supply chain network (Fine, 1998). Companies face major challenges of having to deal with shortened product life cycles in addition to partitioned markets, increased demand uncertainties, and leaner business operations. Even the most technologically advanced companies are struggling to understand the changes in the market, which has led companies to focus both on adaptability (longer term adjustment) and agility (shorter term adjustment) to respond to market changes (Lee, 2004). As an example, Cisco relied on its own forecasting system based on years of high growth in the late 1990s only to end up stockpiling inventories of finished goods and components of routers and switches, which were primarily high tech items then (Berinato, 2001). Having failed to understand the nature of its products and shortened life cycles, Cisco had to take \$2.2 billion of inventory write-off, the largest in the history of business to date.

Optimizing inventory and replenishment policy is no longer an isolated problem restricted to individual business entity. Recent research and business practices point to the fact that the issue of shrinking product life cycles (or selling seasons) should be approached from a systematic view or with a holistic approach (Chen and Pundoor, 2006). That is, it is crucial for individual businesses to develop ways to collaborate among supply chain partners to thrive in the new business settings. This new perspective on shrinking selling seasons and increased uncertainties has provided an incentive to develop extended supply chain collaboration and integration initiatives by businesses (Fleider 2003).

Traditionally, a short selling season problem in inventory management has been studied using the newsvendor model, where production and delivery lead times may be longer than products' selling season. In a newsvendor problem, coordination can be achieved by inducing the buyer to order more to avoid under-stocking situations. The vendor may propose a supply chain coordination mechanism such as the return policy, sales rebate policy, or volume discount to increase order quantity and sales (Yao, Leung, & Lai, 2008; Xiao & Qi, 2008; Qi, Bard, & Yu, 2004; Webster & Weng, 2000). One of the key elements to achieving a successful coordination in supply chain is having the right incentive aligned mechanism in place when information is hidden and interests are incompatible amongst different stakeholders. A number of research streams study the need for aligned incentives from microeconomics perspective (Radner, 1987; Groves & Loeb, 1979; Marschak & Radner, 1972), in marketing studies (Tsay, 2001; Padmanabhan & Png, 1997; Pasternack, 1985; Jeuland & Shugan, 1983), and under decentralized supply chain settings (Giannoccaro & Pontrandolfo, 2004; Chen, 1999; Porteus & Whang, 1991). Among topics that display relevance to our paper is a study on supply chain coordination under retailer competition. Bernstein and Federgruen (2005) investigate the equilibrium behaviours of competing retailers in designing contractual agreements. Also, extending on single period model, Xiao and Qi (2008) develop two-period model for a supply chain consisting of one manufacturer and two competing retailers under production cost disruptions. Our paper studies a supply chain coordination mechanism under retail competition for items with short selling seasons. The primary contribution of this paper lies in providing insights on identifying settings under which coordination and competition could jointly improve supply chain performance both at global and at local levels.

## **2. OBJECTIVE AND RESEARCH QUESTIONS**

This paper studies a supply chain and marketing problem that is both practical and relevant in nature: a shrinking selling season in fragmented customer markets. Examples of products that can be applied in this scope include innovative and high tech items, periodicals, perishable goods, and fashion goods, all of which exhibit time-sensitivity of delivery to the market. Various forms of mechanisms are known to be incentive compatible and have had degrees of success in real business settings, such as buy-back contracts (periodicals or weekly magazines), revenue sharing contracts (DVD rentals), and vendor managed inventory (among retailers and manufacturers). With demographic changes and technological advances that accelerate both demand and supply cycles, the scope of products that fall under this category for short selling season is expected to increase (Fine 1998). The objective of this research is to assess the effectiveness of the return policy for items with short selling season under retail competition, and to identify settings under which right incentives could be established for different stakeholders in supply chain to achieve both profit-sharing and risk-hedging.

Specifically, we intend to address the following research questions:

- How do structural parameters (e.g., the degree of demand variability and retailer heterogeneity) impact supply chain performance when return policy is implemented with competing retailers?
- How do coordination (i.e., the return policy) and competition impact supply chain performance jointly as well as in isolation?
- What are settings under which the incentive compatible return policy is beneficial for the entire supply chain under competition?

## **3. SUPPLY CHAIN COORDINATION AND RETAILER COMPETITION**

We investigate a two-stage supply chain consisting of a single vendor (manufacturer) supplying two retailers with a single stock keeping unit. Each retailer faces demand from end customers, and the vendor, in turn, replenishes the item from an external supplier (Figure 1). In particular, we consider a setting in which a short selling season prevails. We believe this business setting is gaining relevance both in practice and academic

research with shrinking product life cycles being one of the major trends as well as challenges in contemporary supply chain. This research proposes a coordination policy known to be incentive compatible for replenishment of items with short selling seasons in a decentralized system where each stakeholder naturally pursues its own goal which may not be aligned with the overall benefits of the supply chain (Lee & Whang, 1999).

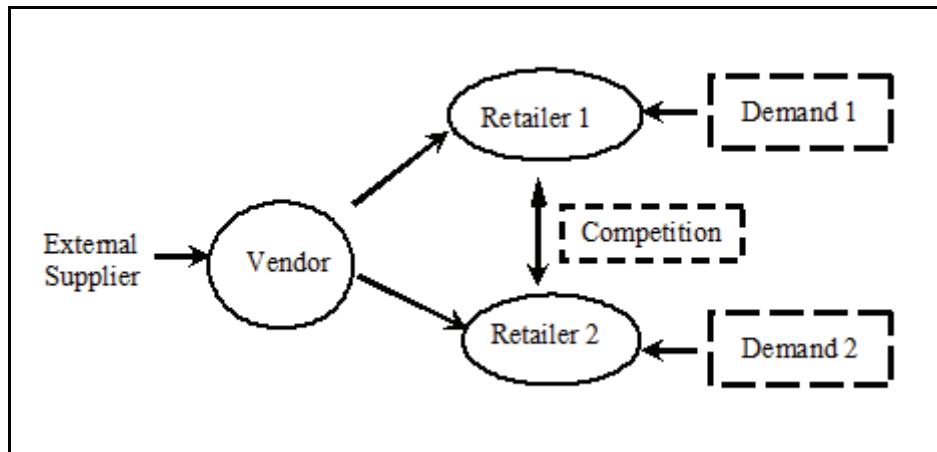


Figure 1. Two stage supply chain: One vendor – two retailers

Two retailers are assumed to be of a comparable size and are *in competition* with each other in the sense that the end customers choose to switch to the other retailer if there is a stockout situation in the retailer of their original choice. The assumption of competition holds well as the supply chain faces short selling season and customers cannot afford to wait (i.e., not loyal or impatient) for the shortage to be filled by the retailer of their choice. Supply chain coordination between the manufacturer and retailers is proposed via the return policy to maximize throughput through the system while enabling risk hedging at the retailer level. It should be noted, however, that the risk does not completely disappear from the system, but shifts upstream to be shared with the manufacturer.

As per Pasternack (1985), the optimality of the return policy in the multi-retailer environment is only achievable if unlimited returns are allowed for partial credit, which satisfies the following relationship:

$$c_1 = (p + g) - \frac{(p + g_2 - c)(p + g - c_2)}{(p + g_2 - c_3)}$$

where

$c = c$  = unit manufacturing cost

$c_1$  = unit wholesale price (paid to the manufacturer)

$c_2$  = unit credit paid to retailers for returns

$c_3$  = unit salvage value

$p$  = unit retail price

$g$  = unit goodwill cost at each retailer

$g_1$  = unit goodwill cost at the manufacturer

$g_2 = g + g_1$  = unit goodwill cost incurred by the system

In particular, this research focuses on the study of the impact and dynamics of the *competition* dimension in a two-stage supply chain facing a short selling season. We also consider a second dimension, namely *information transparency*, to allow settings for supply chain coordination. With information transparency in place for a decentralized system, replenishment decisions at the retailer are made in a transparent manner in such a way that the implementation of an incentive aligned return policy is warranted. For the purpose of exposition of our model, we consider all four cases as outlined in Table 1: (I)

no coordination without competition, (II) coordination without competition, (III) no coordination with competition, and (IV) coordination with competition.

	<b>No Coordination (non-transparent SC)</b>	<b>Coordination (transparent SC)</b>
<b>No Competition</b>	I. No coordination & no competition (Base Case)	II. Coordination & no competition (Pasternack's Model)
<b>Competition</b>	III. No coordination & Competition	IV. Coordination & Competition

Table 1. Two stage supply chain: One vendor – two retailers

Case I will be used as the base case with neither coordination nor competition in place. Of particular interest to this research would be joint effects (case IV) as well as isolated impact of coordinated return policy (case II) and competition (case III) on supply chain performance. Supply chain profitability with the coordinated return policy is expressed as in Pasternack (1985) as:

$$EP_s(Q^*) = (p - c)\mu - \sigma(p + g_2 - c_3)\phi\left(\frac{Q^* - \mu}{\sigma}\right)$$

where  $Q^*$  satisfies

$$F(Q_s^*) = \frac{p + g_2 - c}{p + g_2 - c_3}$$

for the distribution function  $F(\cdot)$  of demand which follows a normal distribution  $x \sim N(\mu, \sigma)$ .

Two competing retailers are assumed to be of comparable size in demand; however, we allow heterogeneity of retailers in demand variability by varying coefficient of variation (cv) of demand at each retailer. The effects of the degree of retailer heterogeneity are also revealed and discussed via simulation experiments.

#### 4. NUMERICAL RESULTS AND MANAGERIAL INSIGHTS

##### Simulation Settings

Parameters and assumptions used in the simulation experiments of the base case (no coordination & no competition) are summarized in Table 2. For all cases with coordination (i.e., return policy), the wholesale price ( $c_1$ ) and return credit ( $c_2$ ) will be determined separately for each run to maximize profits at either local or global level based on values of coefficient of variation (cv). Also, unlimited return (100%) is assumed for any leftover inventory at each retailer at the end of each period.

<b>Cost parameters (per unit)</b>	<b>Demand parameters &amp; assumptions (at retailer)</b>
$c = \$12.00$	$\mu = 500$
$c_1 = \$15.00$ (no coordination)	$cv = 0.05, 0.1, 0.2, 0.3, 0.4, 0.5$
$c_2 = \$0.00$ (no coordination)	
$c_3 = \$5.00$	Total 2,000 replications (1,000 periods for each replication)
$p = \$25.00$	Demand at each retailer follows a normal distribution
$g = \$5.00$	CV determines retailer heterogeneity
$g_1 = \$3.00$	Customers switch to the other retailer under competition in case of a stockout at the retailer of their original choice
$g_2 = g + g_1 = \$8.00$	

Table 2. Parameters and assumptions of simulation experiments

The simulation package, Crystal Ball Professional® was used to run numerical experiments. For each combination of parameters identified in Table 2, simulations of supply chain operations are conducted for 1,000 independent single periods, and the results are summarized over 2,000 replications for each of the four cases in Table 1. The sequence of actions for simulation runs performed at each station for case IV (coordination & competition) is summarized in Table 3.

Sequence of Simulation Run	
Steps	Actions at retailers each single period
<b>R – 1</b>	Stocking decision is made
<b>R – 2</b>	Demand is identified
<b>R – 3</b>	Demand is filled through the single period
<b>R – 4</b>	(i) Excess demand (stockouts) – customers switch to the competitor (ii) Return is made to the manufacturer – full return at partial credit
Steps	Actions at the manufacturer (vendor) each single period
<b>M – 1</b>	Incoming demand is observed from each retailer
<b>M – 2</b>	Demand is fulfilled
<b>M – 3</b>	(i) Excess demand at retailer – no action is taken (ii) Excess supply at retailer – full return at partial credit is given

Table 3. Sequence of simulation run for Case IV: coordination & competition

### Impact of Competition

The impact of competition can be investigated by comparing case I (no coordination & no competition) and case III (no coordination & competition). For both cases, supply chain profits show monotonically decreasing pattern in demand variability expressed as cv. However, percentage improvement in supply chain profits due to competition monotonically increases in cv as shown in Figure 2. Thus, it is apparent from the results that having competition in place is beneficial for the entire supply chain profitability (improvement of 1% ~ 15%) across all values of cv as lost sales at one retailer can be absorbed by the other retailer.

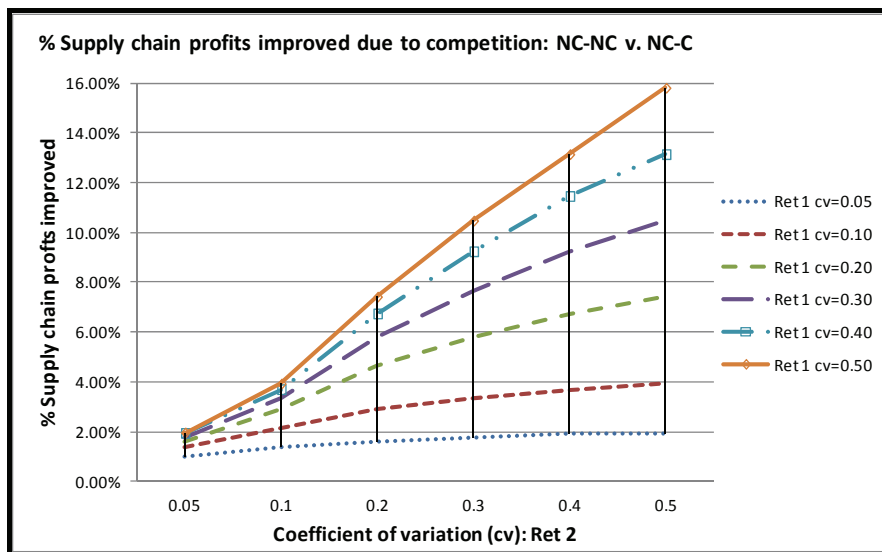


Figure 2. Supply chain profits improved due to competition

This is also explained by the fact that the greater demand variability tends to result in substantial lost sales at each retailer (though not necessarily at the same time), which in

turn, could be fulfilled by the other competing retailer improving both profitability and product availability for the supply chain.

Service levels at each retailer (around 60%) and the system (around 36%) stay constant for the base case, consistent with the theoretical results for the standard newsvendor model. A relatively low system service level for the base case is due to the fact that supply chain experiences stockouts when either retailer runs out of stock, as there is no retailer switching without competition. On the other hand, system service level for case III displays a significant improvement due to retail competition, hovering around 60 ~ 64%, a huge increase from case I. It should be noted that the greatest improvement on system service level is achieved when two competing retailers are relatively homogeneous (Figure 3). That is, competing retailers who are both capable of absorbing balanced amount of stockouts from the other retailer prove to be beneficial in terms of overall supply chain product availability.

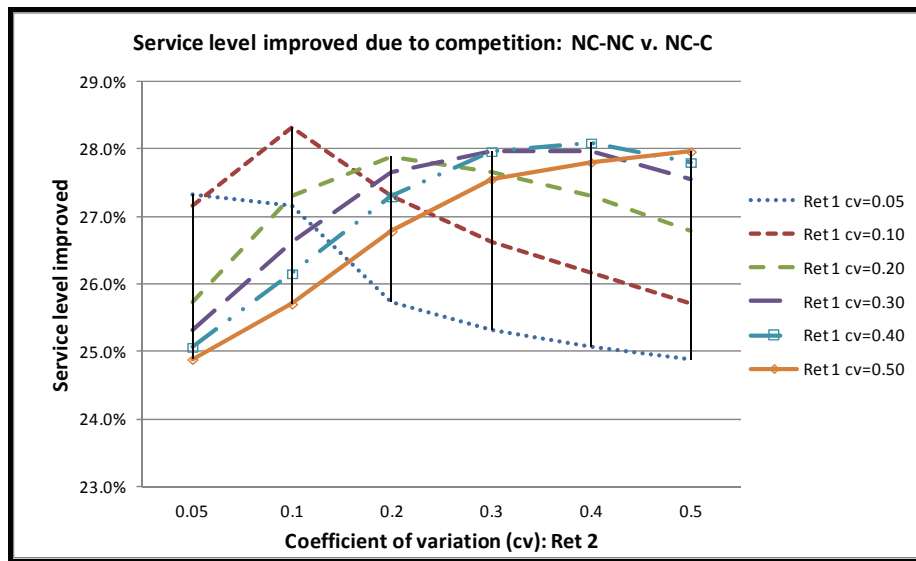


Figure 3. Service level improvement due to competition

Also the percentage of lost sales switched due to competition (11% ~ 39%) is greatest when retailers are homogeneous, consistent with the results obtained on the system service level improvement observed in Figure 3, as the lost sales switched to the competing retailer are immediately converted to an improved system service level.

### Impact of Coordination

The isolated impact of coordination is revealed in case II (coordination & no competition), the standard case of supply chain coordination attained by implementing return policy as proposed by Pasternack (1985). The wholesale price and partial return credit are identified to achieve optimal coordination at the manufacturer, retailers, or the system. In general, higher stocking level at each retailer as a result of the return policy provides risk hedging for the retailer and increased sales for the supply chain. Improvement in supply chain profitability from coordination increases across all values of cv as shown in Figure 4. That is, the higher the cv, the higher the percentage increase in supply chain profitability (ranging from 0.34% to 5.16%) due to coordination, although the impact is not as pronounced as the impact of competition generated via inventory pooling effect.

Further, in comparing the isolated impact of coordination versus competition, we note the results are consistent across all supply chain parameters used. Retail competition tends to create a setting in which inventory pooling effect is evident for the entire system, significantly improving supply chain service level without having to increase stocking level at each retailer. On the contrary, coordination improves supply chain performance

(profitability or service levels) by increasing stocking level at each retailer, which does not completely remove the cost of overstocking from the system's perspective.

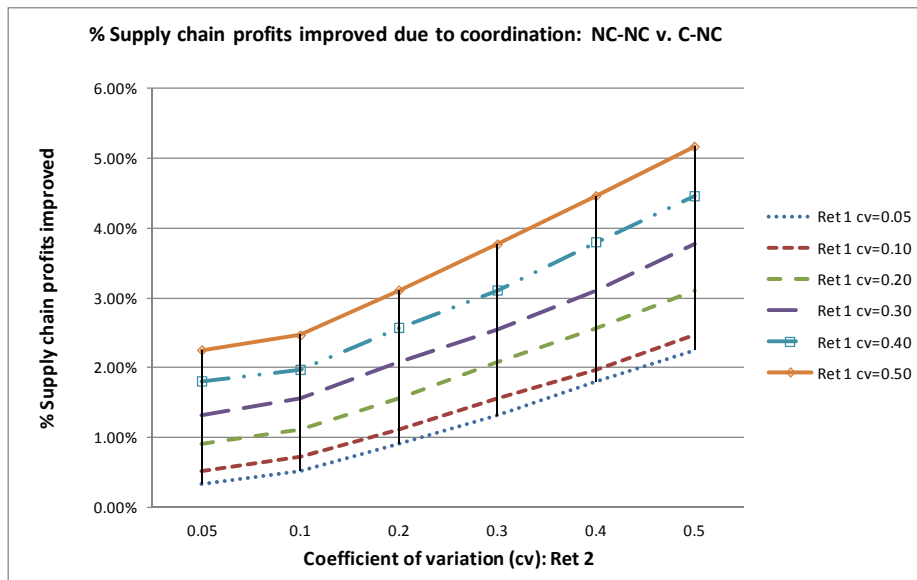


Figure 4. Supply chain profits improved due to coordination

### Joint Effects of Competition and Coordination

The joint effects of competition and coordination are revealed in the results of case IV, which studies supply chain benefits of retail competition with coordination in place. The supply chain can indeed benefit significantly by having competing retailers in addition to the reduced lost sales and the increased service level due to coordination. In case of lower than expected demand, however, high stocking levels from coordination could be costly for the supply chain, which is not mitigated by having competing retailers. While joint effects of competition and coordination still show a clear and consistent improvement of supply chain profitability in cv, it is evident from Figure 5 that the major portion of improvement in profitability or service levels is attributable to competition, with the contribution from coordination effects being marginal at best.

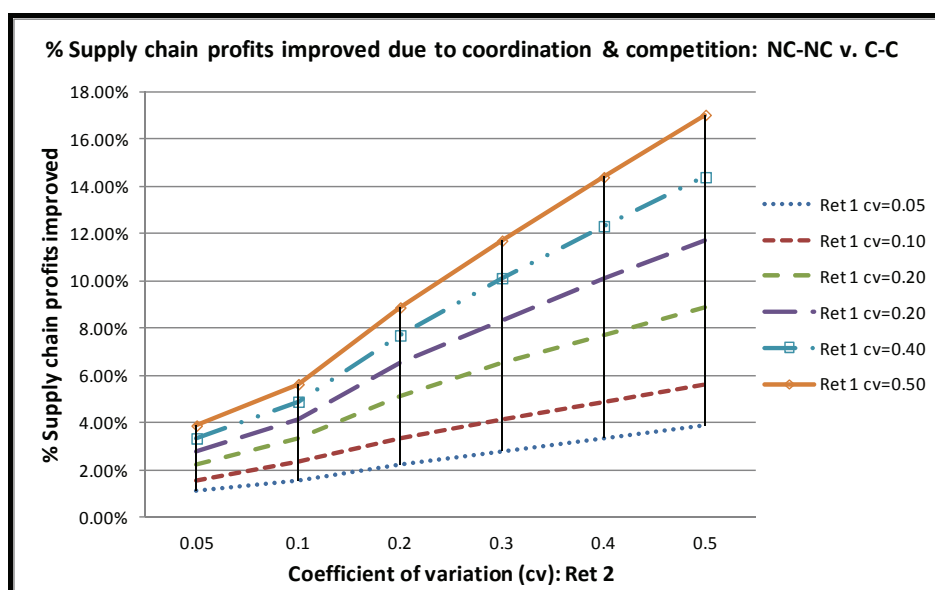


Figure 5. Supply chain profits improved due to both competition and coordination



Finally, we consider a *benchmark case* in which a single retailer – single manufacturer is assumed with and without the coordinated return policy (Table 4). This should provide the first best solution for the numerical experiments, as the single retailer system should provide optimal stocking level for the whole supply chain without overstocking, often observed with two or more competing retailers. It is interesting to note that case IV – with both competition and coordination – provides significantly higher system-wide service levels than the benchmark cases, yet produces lower profitability (especially for higher values of *cv*) due to overstocking at the retailer level.

Supply Chain Profits							Supply Chain Service levels					
cv	0.05	0.1	0.2	0.3	0.4	0.5	0.05	0.1	0.2	0.3	0.4	0.5
Case I	\$12,513	\$12,023	\$11,048	\$10,077	\$9,112	\$8,213	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%
Case II	\$12,555	\$12,109	\$11,221	\$10,333	\$9,458	\$8,637	56.2%	56.2%	56.3%	56.2%	56.3%	56.3%
Case III	\$12,638	\$12,283	\$11,563	\$10,845	\$10,155	\$9,510	63.3%	64.4%	63.8%	64.0%	64.1%	63.9%
Case IV	\$12,653	\$12,304	\$11,613	\$10,917	\$10,235	\$9,612	83.2%	83.2%	82.8%	83.0%	83.0%	83.0%
Benchmark - no coord	\$12,655	\$12,311	\$11,620	\$10,928	\$10,238	\$9,551	60.0%	59.9%	60.0%	59.9%	60.1%	60.0%
Benchmark - coord	\$12,686	\$12,372	\$11,740	\$11,111	\$10,488	\$9,858	75.0%	75.2%	74.9%	75.0%	75.0%	74.9%

Table 4. Summary of numerical results

## 5. CONCLUSION

This paper studies the effectiveness of the return policy for items with short selling season under retail competition. Results indicate that the impact of competition is more pronounced than that of coordination in a decentralized system supplying items with short selling seasons. Competition also creates inventory pooling effects between retailers resulting in greatest improvement in the system service level when competing retailers are more or less homogeneous in terms of demand variability. Further, supply chain profitability displays significant improvement under competition and coordination for cases with higher demand variability (*cv*) at retailers, implying that adverse supply chain settings (with high *cv*) provide greater room for improvement via competition or coordination.

The study of identifying the right incentives in a decentralized supply chain for products with shrinking life cycles can be extended to a parallel study of service industries such as travel, rental, accommodation sectors, where stocking is not feasible by nature. Thus an extension or application to a yield management is a possible venue for future research. Further, with trends towards diverse and fragmented marketplace, the development of different incentive models to accommodate shrinking cycles on both demand and supply sides could also be relevant research agenda.

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# CONTINGENCIES FOR INTERNET LOGISTICS IN FASHION CHAINS

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## INTRODUCTION

The popularity of online shopping has increased quite dramatically in recent years. On Wikipedia one can even find an extended description of the phenomenon. Ghezzi et al. (2012) give details of year-on-year growth. Nevertheless, it is still a young phenomenon. The first commercial server and browser opened only in 1991 (Wikipedia, 2013). Online shopping, also often referred to as "e-commerce", is a concept that is still not yet very well established as a field of investigation. This may be due to the diversity of approaches taken and the number of disciplines, such as Information sciences, Marketing and Logistics, from which it can be studied. Some put the emphasis on the IT aspect or the marketing channel (processes necessary to transfer goods over the Internet), whereas others stress logistics (including a wide ranging topics related to supply chain integration) (Aurumo et al., 2002). E-commerce can be viewed as a marketing channel and hence has to perform three tasks: exchange of goods (physical distribution), exchange of money (transaction facilitation) and the exchange of information (communication) (Web, 2002). The Internet plays a crucial role in connecting buyer and seller and in facilitating the exchanges of money and goods, however, it is unable to perform the physical distribution of tangible goods yet this is most time- and cost-consuming task. This study concentrates on this, the logistics, part of e-commerce. E-traders need channel partners and although some intermediaries maybe skipped (e.g. national distribution centers), other partners (e.g. logistics service providers) may get involved instead. The latter are the 'logistical engine' behind online sales (Webb, 2002). To what extent changes occur in the value chains, depends on the e-traders' strategy and on the type of products that is sold. E-traders can be 'pure' players, or apply a multi-channel strategy in which the internet is but one of the channels. Although the latter can combine the best of the different worlds, it also faces the challenge of channel conflict (Web, 2002). In addition to this, Pache (2001) distinguishes three virtual market segments: standardized goods, entirely customized goods and mass customized goods. Another distinction is type of goods is: convenience goods, shopping goods and specialty goods of which the latter is not too suited for e-commerce (Pache, 2001). Despite the work already undertaken to provide insights into products segments and classifications by types channels and goods, it is not yet clear how logistics functions in e-commerce should best be organized (Pache, 2001; Aurumo et al., 2002; Ghezzi et al. 2012). As these distinctions indicate that no existing structure will fit all possibilities, in this paper we try to develop scenarios to support the organization of logistics structures in various e-commerce contexts.

The rest of this paper consists of a literature review on what logistical processes may look like in different e-commerce contexts with the aim to develop a framework to analyze and compare e-commerce contexts in order to optimize their logistics structures. In the analysis we re-interpret the data obtained by Ghezzi et al. (2012) from 28 case studies of Italian web shops. In the discussion section, the framework and the

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experiences are compared in order to be able to draw conclusions, which are presented in the final section.

### **LOGISTICS STRUCTURES IN B2C ELECTRONIC COMMERCE CONTEXTS**

E-commerce results from the interplay of technological innovations and their adoption by users such as firms, and individual consumers. This adoption has consequences for the main components of supply chains, such as suppliers, producers, distributors (e.g. wholesalers or carriers), retailers and end consumers, who are active in the interplay (Hesse, 2002). The major change and innovation occurs at the front end of the transaction, where the consumer and the e-trader exchange information directly via the Internet, which speeds up the order-placing and payment processes. Also at the back end of the chain changes occur, in particular in logistics processes. A first consequence is the shift from push towards pull (Pache, 2001), as the consumers no longer buy the product from stock in a shop, but orders it from an e-trader further upstream in the supply chain. Another change can be disintermediation if one or more of the actors in the chain lose their position, e.g. disintermediation of the wholesaler if the producer starts an online shop and sells its goods directly to customers. On the other hand the chain can be expanded. New or additional, logistics service providers and couriers or parcel services are required to deliver goods to the doorstep of the consumer (Hesse, 2002). Table 1 summarizes the major differences between E-commerce structures and traditional ones.

<b><i>Difference \ Structure</i></b>	<b><i>Traditional</i></b>	<b><i>E-commerce</i></b>
Orders	Predictable	Variable
Order cycle time	Weekly	Daily or hourly
Distribution planning	Supply-driven, push	Demand-driven, pull
Customer service	Reactive, rigid	Responsive, flexible
Demand	Stable, consistent	More cyclical
Destinations	Concentrated	More dispersed
Order fulfillment	It comes when it comes	Value added functionality over the web
After sales service	Second priority	Key to survival
Competition	Mostly known	Unlimited
Distribution focus	Volume	Small, frequent

Table 1: Differences between e-commerce and traditional structures  
(Based on: Pache, 2001; Hultkranz and Lumsden, 2001; VIL, 2011)

The changes in the supply chain affect many of the logistics processes. Depending on which party in the supply chain opens the online shop, inventory may move up or down the chain. Orders will be picked in the warehouses where these inventories are being held and consist of what just one individual consumer has ordered. Often the goods are delivered at the house of the consumer. This is convenient for the consumer, but home delivery is costly for the e-trader as the process is labor-intensive, whereas the size of the transaction may only be small. Another change is the introduction of processes to manage the return of unwanted or damaged goods, which is seen as key to attracting and retaining customers. Again this is a costly process as it consists of a range of labor-intensive activities. E-traders have to balance these aspects (Rupnow, 2005). Online shops can be established either by existing partners in a supply chain, or by newcomers.

Whether existing partners can and will open an online shop depends on their power in the supply chain as well as the options they see for additional sales. They often need to consider if the new channel will increase sales and not just cannibalize sales from the channels already in-use? Newcomers are often IT-based firms with a focus on web design, IT applications or pure online retail (Hesse, 2002). These pure players lack knowledge and experience in logistics and physical distribution and have to outsource much of these activities (Pache, 2001).

In the literature, much emphasis is put on the limited number of products that are well-suited for e-commerce: consumer electronics, books, CDs, and apparel (Hesse, 2002; Madlberger and Sester, 2005; Ghezzi et al., 2012). These are typical online shopping goods and consumers like to be able to collect information and comparing offers from different suppliers. The Internet offers good opportunities, facilitates and even encourages this type of buying behavior. Another type of product, groceries, are also often mentioned in studies (Madlberger and Sester, 2005; Ghezzi et al., 2012). Many consumers don't want to put effort in buying and collecting these convenience goods from stores. Especially, if the goods are can be delivered to their home, then life becomes easier.

Logistics activities as well as strategies have to fit in the overall business activities and strategies. In the case of e-commerce, technological innovations occur at the front end of the business (Hesse, 2002). Hence the logistical back-end activities have to be adapted to reap the full benefit of these innovations. Logistics strategy is one of the functional strategies in a business. Functional strategies are the tools to achieve the overall business goals, leading to the business strategy (Slack and Lewis, 2003). Consequently, logistics, marketing and IT strategies respectively must fit into the overall business strategy. These strategies may differ for various product/market segments.

Based on the types of products (convenience vs. shopping goods) and on the marketing channels (pure players vs. multi channel player) we distinguish four scenarios. For each of the scenarios we elaborate on three processes: inventory, delivery and returns

### **Inventory**

Hultkrantz and Lumsden (2001) investigated four different distribution channels in which one of the players was removed and hence the inventory was no longer held by this player. For example, if the 'bricks and mortar retailer is removed, consumers will be supplied immediately from a local warehouse. There the order is picked and packed and is delivered directly to the consumer by a truck or van. This can also be applied to, for example, buying flowers, in which case the flower shop is removed from the chain. If the local warehouse is removed, postal services could be used to distribute the goods from the national warehouse to the customer. In the warehouse the goods are picked and packed and then brought to the local post office. The national postal services see that the goods are delivered. This can be applied for example to apparel. Another option could be to distribute the goods with the help of a logistics service provider. This could be applied for large goods with low value density. The fourth channel distributes immediately from the producer by mail. This can be applied, for example, to special products assembled on order. Ghezzi et al. (2012) distinguish six logistics strategies for e-traders with different configurations of inventories. In the supplier managed strategy, the supplier holds inventory and picks orders. If goods from more than one supplier have been ordered by a customer, the goods of all suppliers can be assembled either at the merchant or at one of

the suppliers. In case of supplier managed inventory, the supplier holds the inventory and the merchant collects a number of consumer orders and orders the aggregate number of goods. Upon delivery by the supplier the merchant picks the order for the individual consumer. In case of distributed inventory, the merchant holds inventory for a limited number of very attractive goods, whereas the supplier holds inventory for the other goods from the assortment. Consumer orders are picked where the inventory is held. In case of consignment inventory, the supplier holds inventory, but some of it is kept by the merchant. The latter will pay upon sales. The orders are picked at the merchant. In the case of merchant managed inventory and full in-source, only the merchant holds inventory and picks orders.

### **Delivery**

Hultkrantz and Lumsden (2001) emphasize two aspects of delivery: point respective time of delivery. The authors distinguish four points of delivery of which home delivery is the most appreciated, while the drop-off point approach is in general the least favored. In between are deliveries at the work place and at the post office. With respect to time of delivery they show that the most attractive timeslot is on weekdays between 18.00 and 20.00 (over 60%). Saturday, Sunday and weekdays between 20.00 and 22.00 score about 40% and between 16.00 and 18.00 somewhat below 40%. Consumers favor weekdays between 8.00 and 16.00 less, with a score of less than 20%. Madlberger and Sester (2005) studied consumers expectations concerning delivery time for various products: groceries (convenience goods), books/music, computer and apparel (shopping goods). Consumers expect groceries to be delivered within one day but preferably within between one and four hours. Consumers expect shopping goods to be delivered somewhere between two and fourteen days, but books sooner than computers and apparel. With respect to point of delivery, the authors show that home delivery is favored most, for all products. Workplace is less attractive, but acceptable for all products. Books/music and apparel differ significantly from groceries and computer with respect to where they should be picked up: stores and deposit boxes are favored. The differences for gas/railway station do not differ significantly for the different products. Consumers seem to expect to see a delivery messenger for groceries, but the convenience goods either by mail or a messenger.

### **Returns**

Product returns are unavoidable in e-commerce retail stores. A high level of customer service is expected, of which returns are an essential component. The ease with which goods can be returned, is key in attracting and keeping online customers. However, a firm should not only address its customers' needs, but also its own needs, i.e. costs. Among the most returned goods are: apparel (27%), computer software (20%) and books (15%) and for almost 90% of potential buyers return policy influences their decision (Rupnow, 2005). Xu and Jiang (2009) mention a return rate of even 36%. In the past returns were pretty cumbersome for consumers: bureaucratic rules (e.g. authorization before return) and costly (e.g. return postage), but nowadays it is much easier (notification of return by consumer instead of authorization by e-trader) and cheaper (free return postage) (Rupnow, 2005). However, Xu and Jiang (2009) found that e-traders may also choose to follow a zero return policy for relatively cheap products and one-time consuming goods.

Table 2 presents the framework to support the decision making on logistics structures and content of logistics processes for various e-commerce scenarios.

<b>Product Strategy</b>	<b>Convenience</b>	<b>Shopping</b>
Pure player	<i>Inventory:</i> outsourced to suppliers (Hultkranz and Lumsden, 2001; Ghezzi et al., 2012) <i>Delivery:</i> messenger delivers goods at home within a day (Hultkranz and Lumsden, 2001; Madlberger and Sester, 2005) <i>Returns:</i> zero returns policy goods are relatively cheap and one-time consumed (Xu and Jiang, 2009)	<i>Inventory:</i> outsourced to suppliers (Hultkranz and Lumsden, 2001; Ghezzi et al., 2012) <i>Delivery:</i> postmen deliver at home or in deposit box (Hultkranz and Lumsden, 2001; Madlberger and Sester, 2005) <i>Returns:</i> low cost, simple procedure with adequate instructions; processes at supplier effectively and efficiently organized (Rupnow, 2005)
Multi-channel player	<i>Inventory:</i> at merchant (Ghezzi et al., 2012) <i>Delivery:</i> at home or at a store, within hours by a messenger (Hultkranz and Lumsden, 2001; Madlberger and Sester, 2005) <i>Returns:</i> zero returns policy goods are relatively cheap and one-time consumed (Xu and Jiang, 2009)	<i>Inventory:</i> at supplier and/or merchant: distributed, consignment <i>Delivery:</i> at home, workplace, store or deposit box by mail or a messenger within days or weeks (Hultkranz and Lumsden, 2001; Madlberger and Sester, 2005) <i>Returns:</i> low cost, simple procedure with adequate instructions; processes at e-trader effectively and efficiently organized (Rupnow, 2005)

Table 2: Framework to support decision making on logistics in e-commerce

## ANALYSIS

Ghezzi et al. (2012) analyzed 28 Italian e-commerce merchants to identify logistics problems and logistics strategies. The aim of their paper is to see how logistics strategies have to be adapted to logistical problems. The 28 cases represent all main product industries and show a diversity of business models. In their research, the result is that five of the cases, in two sets, have one strategy for a specific type of problems, whereas in the other 23 cases the relationship is not that straightforward. For one type of problems they find three types of strategy and for another type two. On the other hand, one strategy seems to solve two different types of problems. The authors explain these confusing results with the help of the level of power of parties in the supply chain and characteristics of market segments, i.e. single versus multiple channel and product range. We re-interpret their results using the framework developed before in four steps. First we categorize the cases in the four product market segments we distinguish. Then we identify the types of problems the firms in each of the segments face, we do the same for the strategies. Finally we analyze the fit of problems and strategies in each segment.

From the 28 cases, 16 were so-called traditional sellers with an online shop in addition to a 'bricks and mortar' shop, these we label as multi channel players. Three of these sell groceries, a convenience good. From the remaining 12 cases (pure players) three were labeled 'online clubs', offering a limited range of 'left-overs' of apparel to members who buy impulsively because of the very low price. These 'online clubs' we consider as convenience goods as they are not bought because of their appeal but because of the low

price. In the end we have 3 multi-channel and 3 single channel shops selling convenience goods and 13 multi-channel and 12 single channel shops selling convenience goods.

Ghezzi et al. (2012) identified logistic problems based on product and service complexity, labeled as comparative easy, service complex (high complexity on service, low on product), product complex (high product complexity, low on service) and highly complex. Except for returns management the service complexity varies slightly across types of products. Returns and cycle are important for apparel, whereas cycle time, punctuality and flexibility are important for groceries. For consumer electronics and books the service aspects don't score high. The importance of product aspects differs considerably among the types of products. Value density is important for consumer electronics and apparel, whereas product range is important for books etc. obsolescence and specific needs are important for apparel and groceries. From the 28 cases, 23 are straightforward (15 easy and 8 highly complex) and 5 have a mixed score (two product and three service). From the six shopping goods cases, the three single channel ones score easy, the multi-channel ones score complex. From the shopping goods, six of the multi-channel shops score easy (consumer electronics and books) but seven score high (apparel), whereas six single channel cases score easy, the other two score high on product range and one also on returns: two score product (consumer electronics) and one scores high (apparel).

Ghezzi et al. (2012) distinguish six logistics strategies based on four criteria: inventory ownership and locations, order picking, order assembly and order delivery policy. The former three correlate strongly as orders are picked where the inventory is and often assembled as well if some items come from another source. From the convenience goods cases, the three multi-channel shops follow the full in-source strategy as the merchant is in charge on all four aspects. The single channel cases score supplier managed inventory as the supplier holds inventory. The merchant picks and assembles the order and courier delivers. All but one of the thirteen multi-channel shopping goods cases follow the merchant managed inventory strategy as the merchant is in charge on all aspects but delivery, which is carried out by a courier. The majority (5) of the single channel shopping goods cases follow the distributed inventory strategy (inventory can be either at the supplier and/or at the merchant, but delivery is by a courier), others (2) follow supplier fully managed, merchant managed (1) or consignment inventory (1).

Table 3 presents problems and strategies in each of the four segments and analyzes to what extent combinations of problems and strategies fit and show unique solutions.

<b>Strategy\Product</b>	<b>Convenience</b>	<b>Shopping</b>
Pure player	<i>Problem:</i> easy (3) <i>Strategy:</i> supplier managed inventory (3)	<i>Problem:</i> easy (6), high (1), product (1) <i>Strategy:</i> distributed inventory (5), but also supplier full managed, merchant managed inventory and consignment inventory
Multi-channel player	<i>Problem:</i> service (3) <i>Strategy:</i> full in-source (3)	<i>Problem:</i> easy (6) <i>Strategy:</i> merchant managed inventory (5), but also distributed inventory <i>Problem:</i> complex (7) <i>Strategy:</i> merchant managed inventory (7)

Table 3: Logistics problem and strategy of 28 cases



## **DISCUSSION**

From the literature (Webb, 2002; Pache, 2001) one would expect that a framework that should support the design of a logistics strategy would start from differences among product market segments. However, Ghezzi et al. (2012) start from logistical problems and found a straightforward one-to-one relationship in only five out of their 28 cases. They explained the overlapping results for the remaining 23 cases with the help of "level of power" in the supply chain or characteristics of the market segments. For the complex problems, the merchant can negotiate consignment inventory if he is strong enough to dominate the supplier. For the easy problems, merchant managed applies in case of multi channel merchants who benefit from synergies between channels but suffer from channel conflicts. Pure players face different problems depending on the type of products. Pure players, selling a broad range of shopping goods may opt for distributed inventory. Those who sell convenience goods may opt for supplier managed inventory because of cycle time and price reduction reasons. When taking the product market segments approach, 23 out of 28 cases give a straightforward outcome. Most of the confusing cases are in the segment of the pure players selling shopping goods. This may be because it can be difficult to select which products to select to store at the merchant, either none excel, or none are 'grey' enough. Another striking feature in this segment is the difference in the type of problems: one product-related (because of product range) and one high (because of returns and product range). Consequently, these five cases do differ, either because of the score of one or two aspects of product and/or customer and where the boundary between categories is. The literature (Hesse, 2002; Hultkrantz and Lumsden, 2001) suggests three processes are relevant in e-commerce: inventory, delivery and returns. Ghezzi et al. (2012) identified four, namely: inventory, order picking, order assembly and delivery. However, the first three of these they consider as very strongly related: you pick where the inventory is and assemble only in case of multiple suppliers involved in one individual order. In only one of their six strategies these three are divided strictly among supplier and merchant. On the other hand they don't use returns as a process. Instead returns is one aspect of service complexity, measured as a percentage of returned goods with more than 10% as the highest score. This figure is low when compared to figures mentioned in the literature (Xu and Jiang, 2009; Rupnow, 2005). However, the cases in Ghezzi et al.'s research show that only eight apparel companies reach this highest score, whereas fourteen consumer electronics and books shops have a score of less than six percent only. Rupnow (2005) stressed the importance of an elaborated, well-documented and consumer-friendly return policy. Apparently, the existence of such a policy can overcome some degree of negative perceptions and sentiments among consumers.

Although the literature (Webb, 2002; Hultkrantz and Lumsden, 2001) stresses the importance of very high service levels with respect to speed, flexibility and the like, the analysis does not really support that. Cycle time is important for grocery and to a lesser extent for apparel (shopping goods), but not so much for consumer electronics and books and even less for apparel (convenience goods) (Ghezzi et al, 2012). Madlberger and Sester (2005) found that consumers accept to wait up to one week or even more for computers, books and even apparel, but not for groceries.

## **CONCLUSION**

The purpose of this paper was to develop a framework to support decision making on logistics structures and the content of logistics processes. The framework based on a functional logistics strategy (Slack and Lewis, 2003) revealed more unique combinations,

(i.e. one level of logistical problems and one logistical strategy) than an immediate examination of such problems and strategies as proposed by Ghezzi et al. (2012). In their analysis to understand their results, they provided reasons, like power in the value chain, as well as explanatory aspects, such as marketing channel and product characteristics. This is an additional justification to apply a framework based on a functional logistics strategy in which market channels (single versus multiple) and products (shopping versus convenience) are the determining contingencies. We argue that such a strategy should be the starting point for decision making on logistics structures, and should not just be applied ex-post to understand outcomes.

Returns are a problem in e-commerce, but are less of a problem than some suggest. The problem can be mitigated by the preventive measures and an elaborated and well-communicated returns policy.

The impacts and consequences of e-commerce seem to be exaggerated to a large extent. The optimistic predictions from the early years of this century of high increases in speed in transactions and short cycle times; tremendous cost reductions; footloose inventories and market share of e-commerce have not occurred at the level that was envisioned. Quite some research is still needed to discover what customers really want, as they are the party that has to be satisfied in the end. In addition to that the efficiency and effectiveness of existing value chains in e-commerce has to be determined to identify the need and possibilities for their further optimization.

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# **RECOGNITION OF REVERSE LOGISTICS CAPABILITIES FOR RETAILERS**

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## **INTRODUCTION**

Numerous companies recognized the potential of reverse logistics in obtaining competitive differentiation, improving profitability, reducing inventory investments, etc. Namely, reverse logistics provides the costs savings for all members of distribution channel. It includes all activities associated with a product or service after the point of sale with the ultimate goal being to optimize or to make more efficient aftermarket activities, thus saving money for the companies involved (Rogers and Tibben-Lembke, 1999). In the literature, reverse logistics received increased attention as it reflects the ability of a company to positively influence the relationship that it has with its customers (Horvath et al., 2005). Richey et al. (2005) consider it as a strategic process that captures value through customer satisfaction and cost control. Growing green concerns are making reverse logistics increasingly a competitive necessity on today's market. However, the analysis of the relevant literature (Rogers and Tibben-Lembke, 1999; Zeiger, 2003) suggests that although reverse logistics is gaining much attention, many companies did not fully realize its importance. This induced the authors of this paper to explore whether reverse logistics receives adequate attention by business entities.

As retailers perform a critical role in reverse logistics (Jack et al., 2010), the specific focus of this paper is on retailers and their reverse logistics programs and activities. The paper builds upon the study of the existing literature on reverse logistics and reverse logistics in retailing. The exploratory research used the qualitative approach and authors conducted in depth interviews with senior managers in top retail companies operating on Croatian market. The objective of the study was to explore how significant are reverse flows of products and packaging to Croatian retailers.

After the introduction follows the literature review of reverse logistics in retailing, from this originates the description of the problem. The methods and tools used to gather and analyze the data are explained in the methodology. The study findings are presented in the following segment and the paper ends with recommendations for further research and conclusion.

## **REVERSE LOGISTICS IN RETAILING**

Reverse logistics as a research field is relatively new. It emerged in last two decades and today a significant body of knowledge is beginning to develop around the reverse logistics (Tibben-Lembke and Rogers, 2002). Daugherty, Autry and Ellinger (2001) wrote that reverse logistics is fast becoming a necessity. Still, there is no consensus regarding the concept of reverse logistics, as a number of different definitions such as reverse channels, reverse flow, recycling, reuse and remanufacturing are proposed (Nikolau et al., 2012).

Reverse logistics is defined as "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin, for the purpose of recapturing value of proper disposal" (Rogers and Tibben-Lembke, 1999). However, this definition is considered to be limited in scope. Depending on the type of reverse process employed, products may not necessarily be returned to their point of origin, but to a different point for recovery (De Brito and Dekker, 2003). The Reverse Logistics Association (2009) refers to the reverse logistics "as all activity associated with a product/service after point of sale, the ultimate goal to optimize or make more efficient aftermarket activity, thus saving money and environmental resources". Although in

recent years many definitions emerged, reverse logistics researchers agree that the most well-known definition of reverse logistics is given by the European Working Group on Reverse Logistics. They define reverse logistics as the “process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal”. Krumwiede and Sheu (2002) also found that definitions of reverse logistics largely vary across industry segments.

The reverse logistics flow is usually broken down into two general areas, depending on whether it primarily includes products or packaging, and they are both studied in the literature (Tibben-Lembke and Rogers, 2002). Traditionally, reverse logistics is primarily viewed as the process of recycling products (Krumwiede and Sheu, 2002), but over time new aspects of reverse logistics evolved. Contrary to the importance of forward logistics in the supply chain management and the essential role it plays in the company’s overall performance and customer relations, Autry et al. (2001) noted that reverse logistics is too often overlooked and its strategic value is ignored, usually because companies consider reverse logistics less important than forward logistics.

However, many corporate initiatives and independent enterprises are turning product take-back into cost savings and profits. As a result, end-of-life products are regarded as environmental liability, as economic opportunity, or both (Geyer and Jackson, 2004). The growing interest in reverse logistics among companies is associated with economic and environmental factors (Ravi and Shankar, 2005), especially with an increasing need to address issues of environmental performance and its integration in the supply chain. The issue of ‘greening’ added an additional dimension to the reverse logistics because manufacturers and retailers in certain markets are obliged by the law to take back their products at the ‘end of life’ and recycle them (Walther and Spengler, 2005). According to Marisa et al. (2002), reverse logistics is driven by several forces, such as competition and marketing motives, direct economic motives and concerns with the environment. Reverse logistics also offers opportunity for differentiation among companies or a way in which companies can distinguish themselves with consumers (Daugherty et al., 2002). It is proposed that reverse logistics should “*be seen as an opportunity to build competitive advantage*” (Stock et al., 2002). Richey et al. (2005) noted that if companies want to gain their competitive advantage in order to enhance operational performance and financial benefits, they must allocate more resources to reverse logistics. The position within the supply chain often drives the size and scope of the reverse logistics problems that the company faces and the closer the company is to the end consumer, the greater the size and scope of reverse logistics issues (Tibben-Lembke and Rogers, 2002).

Logistics is not only considered to have a significant impact on a manufacturing organization's performance, but it is also vital to the performance in the retailing context. Leading-edge companies recognized the strategic value of having a reverse logistics management system in place to keep goods on the retail shelf and in the warehouse fresh and in demand (Raicu et al., 2009). Although much was written about many specific aspects of reverse logistics, the collection and disposition of products in the retail context was largely ignored.

Returns are and always were a fundamental part of retailing, so retail reverse logistics emerged as the key management issue within the field of supply chain management. Since retailers deal with customers directly, they usually deal with a larger volume of returned merchandise than their suppliers (Tibben-Lembke and Rogers, 2002).

The need to effectively manage product returns as a part of supply chain management is getting more attention nowadays. Overall customer returns are estimated to be approximately 6% across all retailers (Stănculescu, 2011).

Within the retail sector, two main mechanisms of returns management were identified (Halldórsson and Skjøtt-Larsen, 2007). The first one is the centralized reverse supply chain, where one organization is responsible for collection, inspection, disposition and redistribution of returned items. In the second one, stores act as their own 'gatekeepers', checking returned products and deciding which reuse/disposition paths items should take.

When it comes to organization of reverse flows, four physical network structures for handling retail returns were identified (DfT, 2004):

- A. Integrated outbound and returns network – Using a company's own fleet or its logistics providers' vehicles, returns are 'back hauled' from the retail outlets to regional distribution centre (RDC). The gatekeeper function associated with sorting, checking and deciding the ultimate fate of the returned items is carried out at the RDC. This system works well in a supply chain where the frequency of delivery to stores is high, and the volume of returns is also high.
- B. Non-integrated outbound and returns network – This is the case where a separate network is used for managing returns, typically operated by 3PL that takes returns from stores to a separate location where the gatekeeper activities are undertaken by the retail organization. This system is appropriate when level of returns varies in volume but is generally low.
- C. Third-party returns management – When the total management of product returns is outsourced to a third party logistics, retailer benefits in that no gatekeeping expertise is required at the individual store level. The third party logistics provides this functionality along with a complete returns management process, including supporting technologies, refurbishment and disposition programmes.
- D. Return to suppliers – In this case goods are returned directly to suppliers and exchanged for credit. Under these circumstances, retailers may have no gatekeeping responsibilities and little responsibility for returns. Such systems may have additional transport cost implications as the goods have to return to the individual supplier for the gatekeeping function before potential further travel related to refurbishment or disposition.

## **DESCRIPTION OF THE PROBLEM**

Reverse logistics operations, especially in developing logistics systems, such as Croatia, are at their very beginnings. Ununiformed processes of product return that occur on different levels of supply chain include returning products to vendors, manufacturers, services and wholesalers. Organization of the collection centre for returned items would provide uniformed reverse logistics activities for every product, resulting is less items in the reverse logistics chain, higher preserved value of returned products, less items unnecessarily directed to landfills etc. (Rogic and Bajor, 2012). According to the research conducted in 2010 on 25 companies from different sectors in Croatia, many companies did not implement advanced reverse logistics activities in their systems because they do not recognize reverse logistics activities as strategic ones (Rogic, Babic and Bajor, 2012). The main barriers for intensifying reverse logistics activities, according to research results, are the lack of interest for reverse logistics chain, lack of reverse logistics systems, company's policies, lack of management understanding, financial constraints and lack of educated personal. As uniformed procedures are not common in reverse logistics systems in Croatia, consumers are often returning products to different locations, while the most frequent one is the retail location where the product was bought.

Srivastava and Srivastava (2006) pointed out that reverse logistics issues in Europe are mainly regulatory-driven. Hence, as Croatia is on its way to the European Union, the composite processes of reverse logistics will become additionally complex and pose new challenges in front of companies on Croatian market.

According to Jack et al. (2010), retailers perform a critical role in reverse logistics. On Croatian retail market large food retailers are the leading drivers of development. Despite recession, they operate with growing turnover and number of employees, which make up for almost a quarter of employed workforce in distributive trade (CBS, 2012). In 2011, the leader had market share of 29% and the coefficient of concentration  $K_5$  was close to 60% (CCC, 2013). Hence, authors assumed that large food retailers would be companies that actively implement reverse logistics activities. Consequently, focus in this paper is on reverse logistics in leading Croatian food retailers. The main questions the authors strive to answer are how are systems of reverse logistics for products and packaging organized in leading Croatian food retailers and how could they be improved.

## **METHODOLOGY**

Although the literature on retail reverse logistics is growing in the last ten years, it is still mainly based on theoretical papers, with limited empirical research undertaken to define the management aspects involved (Bernon and Cullen, 2007). Logistics and supply chain research projects mainly focus on forward logistics, but as the costs of reverse logistics are disproportionate compared to forward logistics, the need for conceptual framework on the reverse flow is more than evident, as stated by Bernon, Rossi and Cullen (2011). Also, previous research focused mainly on quantitative studies whereas qualitative studies were neglected.

The objective of this study is to explore whether Croatian food retailers recognized the importance of reverse logistics of both products and packaging for their operations. Due to the exploratory nature of the study, it was felt that a qualitative approach was appropriate. According to Eisenhardt and Graebner (2007) a qualitative approach is particularly suited for gaining a better understanding of collective and individual perceptions, and open or semi-structured interviews are suitable methods for obtaining such perceptual data with respect to a given phenomenon of interest.

As reverse logistics is a complex system, authors concluded that interviews would enable them to gather sufficient and valuable data in a short period of investigation. Consequently, authors conducted ten semi-structured in-depth interviews with senior managers working in logistics and supply departments of food retailing companies.

The research instrument comprised questions related to the return of products, handling the goods that are not sold, the reverse flow of packaging, waste management, etc. A particular emphasis was placed on the system of information flow related to the return of products and the return of packaging. In order to save respondents' time, the research instrument was sent to companies few days before interviewing. The research was conducted in the period March-April 2013.

In accordance with the structure of the research instrument, the analyses and their interpretation first refer to the organization of return of products, and then to the reverse flow of packaging.

## **RESULTS AND INTERPRETATION**

### **The organization of the return of products**

The interviews among retail companies revealed that none of them had a department for reverse logistics and the organization of reverse logistics is under the supervision of other departments. Namely, in every retail company there is a specific group of employees responsible for handling complaints and reverse flow of products. There is no general rule which organizational units such employees come from. The fact is that logistics departments are involved in all cases, and in the majority of investigated

companies also involved are employees from sales and purchasing departments. As investigated retailers belong to the group of large companies, which use IT technologies and innovations in their supply chains, it is not surprising that the Trading and category management departments participate in reverse logistics in two retailers.

All respondents pointed out the role of the Purchasing department in handling the goods not sold:

*"Purchasing department is responsible for making arrangements with suppliers how to handle the goods not sold. Accordingly, it is indirectly responsible for all inefficiencies resulting from such arrangements. Logistics department is responsible only for execution of arrangements the Purchasing department made."*

Respondents reported they used three forms of arrangements between retailers and their suppliers on how to organise the reverse logistics system:

- 1) supplier is responsible for the return of its unsold products (usually supplier delivers his products directly to the store and picks up unsold products from the store)
- 2) retailer is responsible for the return of supplier's unsold products (unsold products are from stores returned to retailer's central distribution centre or logistics distribution centre, and afterwards, to supplier)
- 3) there is no preset procedure for returning unsold products (if a retailer has unsold products, they can agree to return the products to the supplier, retailer can ask supplier to allow them to cut down prices, etc.).

These forms of arrangements are consistent with the findings of DfT (2004) and their identified physical network structures for handling retail returns.

However, all respondents agree that costs related to the return of products are high so sometimes it is not worth organizing the reverse flow. The biggest efforts and costs are related to the documentation and the organization of necessary activities. However, it is difficult to evaluate logistics costs of manipulation, transport and commission.

All respondents mentioned the use of IT solutions for monitoring the flow of products. Conclusively, all of them have some kind of "complaint management system". Also, all stores have strictly defined procedures for the return of products that they need to follow, which are supported with adequate IT solutions. Such systems allow retailers to be constantly aware of types and quantities of goods waiting for the return in the return warehouses.

Respondents stated that they have a very small number of food products returned to stores. Two respondents demonstrated the socially responsible behaviour in their companies, as they at the end of the day give unsold food products like bread to charity. Very often, seasonal non food items are returned to the retailer's central warehouse and are stocked there till the next season. Unfortunately, there are many challenges and costs involved, such as: costs of transportation of unsold products from different stores to the central warehouse, costs of manipulation, labour costs in stores and warehouses, risks related to the damage of products, etc.

### **The organization of the return of packaging**

The study results on return of packaging are similar to those relative to return of products. Like the organization of the return of products, Logistics department is responsible for completing tasks in the reverse flow of packaging.

In managing their returns of packaging, interviewed retailers make distinctions between return of palletes and roll containers, return of plastic/glass bottles and return of other types of packaging. The process of palletes returning is linked to the process of delivery of goods to the retailer's central warehouses. They call it: "*The principle of 1 for 1*". It

should be pointed out that suppliers do not have to wait for their palettes. When suppliers deliver goods to retailers' warehouses, they get the same amount of empty palettes, so the palettes are circulating between retailers and suppliers.

All interviewed retailers use roll containers for the delivery of goods to stores. Similar to palettes, roll containers do not stay in stores, they are returned to the central warehouse upon delivery of products to the store:

*"Roll containers bring multiple benefits to us. Our stores do not have to unnecessarily accumulate containers. After delivery to the store, containers are returned to the warehouse and the same containers are used for further deliveries from the warehouse."* Described systems of returning palettes and roll containers enable companies to keep lower inventory levels of palettes and roll containers, thus resulting in lower costs in the supply chain.

Organization of the return of plastic bottles differs depending on the size and type of store. In general, in small stores an employee is responsible for the return of plastic bottles. Two respondents noted that in their large stores (such as hypermarkets) special machines are used to collect bottles from customers and sort them by their bar codes. Others said that in large stores at least 2-3 employees work on return of bottles. All respondents agree that the biggest costs of the organization of the return of bottles are the labour costs.

For other types of packaging the major issue is how to minimize waste, separate and recycle materials. Food retailers on Croatian market are receiving additional motivation in the form of strict EU regulations that require decreasing waste creation and increasing its use as a raw material or for energy. However, the reverse flow of packaging and particularly waste management are areas with strong potential for significant savings.

The interviews among retailers revealed that all of them realized savings due to reverse flow of packaging. Moreover, all of them agree that their management understands significance of reverse logistics and dedicates sufficient effort to find out how to increase savings related to the reverse flow of packaging. It is interesting that half of the interviewed retail companies do not consider their system for reverse flow of products as very important for savings in their environment protection costs. Moreover, they do not think that their strategy for reverse flow of products has helped them to improve their market position relative to the competitors.

## **Limitations and further research**

**Several potential limitations of this study need to be acknowledged. Firstly, comparing to total number of retail companies operating on Croatian market, a small number of retail companies participated in the study. This is mainly attributable to the limited time and resources available for the study. Therefore, the findings of this research should not be generalized across the entire Croatian retailing. Secondly, the methodology followed and the analytical methods employed in the study were also subject to limitations. The present paper has certainly acknowledged limitations that need to be taken into account when considering the results of the study and its contributions. More generally, as with any academic work, it is hoped that the present paper will stimulate other researchers to conduct more extensive research.**



## CONCLUSIONS

The research findings point to the conclusion that big food retailers on Croatian market are all very active in the field of reverse logistics. Due to the characteristics of their goods, the level of products returned to stores by customers is very low. The return of products mostly occurs due to close expire dates, product damages and seasonality. Therefore, the dominant reverse logistics flows of products are from stores to distribution centres and warehouses and from retailers to suppliers. Taking into account the high costs of product returns, retailers are focusing on increasing the efficiency and efficacy of their operations, especially procurement management, in order to decrease the overall need for return of products.

On the other side, retailers are much more active in the return of packaging, as it is a continuous process, with large volumes and a great potential for costs savings. The major focus is on increasing the speed of reusable packaging flow through the supply chain and to generate savings through waste separation and recycling.

However, management of retail companies often uses the slogan of "conscientious reverse logistics management" for promotion purposes but with poor implementation. In general, there is still a low level of collecting and recycling waste and packaging in Croatian retailers. Thus, retailers on Croatian market could face penalties after entering the EU, or they can seize the opportunity and further improve their reverse logistics.

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## Section 9 – Humanitarian Logistics

### EMERGENCY RESPONSE ANALYSIS TOOLS FOR HUMANITARIAN LOGISTICS

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#### ABSTRACT

In recent years, the increasing frequency of natural disasters poses tremendous challenge to international humanitarian agencies dealing with natural disaster response. However, establishing a resilient humanitarian logistics response for disaster relief has not been widely studied. This paper reviews a currently used emergency response analysis tool, the Emergency Market and Mapping Analysis (EMMA) toolkit, based on the concept of resilience. We compare EMMA with other commonly used response analysis tools such as MIFIRA and HEA. This paper highlights the importance of resilience in emergency response and how critical the effect of disaster response decisions can have on relief work. It will discuss the EMMA framework, analysis process as well as the strengths and challenges of this toolkit.

**Keywords:** Humanitarian Logistics, EMMA, MIFIRA, HEA

#### 1. INTRODUCTION

The essence of resilience in a humanitarian context is the ability of its supply chain to withstand a catastrophic event and quickly return to a state of near normalcy. Therefore, ensuring accurate response immediately after a disaster is critical to enable quick recovery and strengthen resilience. The increasing disaster occurrence attracts greater attention to relief work. In an average year, 134 strong earthquakes (magnitude from 6.0 to 6.9 on the Richter scale) and 17 major earthquakes (magnitude of 7.0 or greater) take place around the world (Sheffi 2005). About US\$65 billion is estimated to be the immediate supply chain impact of the September 11 terrorist attack in 2001. It is estimated that in 2011 alone, there were about 570 disasters which resulted in over 37,000 casualties, 200 million affected people and US\$370 billion in economic damage (Galindo and Batta 2012). The increasing risk and uncertainty in the globalized environment has made it necessary for supply chain managers to build a resilient humanitarian supply chain response network. To minimize the risk and effect of disruptions, adopting a mindset of resilience is of great importance. While many papers address the importance of supply chain risk mitigation and management for resilience, there are not enough resources that refer to the methodologies that can be used for humanitarian response to achieve resilience. In this context, resilience refers to the focus of mitigating the cascading adverse effects of disruptions so that the affected places can recover quickly and resume their normal economic activities.

For humanitarian logistics, being able to react quickly to unpredictable disasters can minimize the loss of lives and alleviate the suffering of beneficiaries. Humanitarian logistics ideally requires zero lead time. Once a disaster takes place, a degraded transportation infrastructure makes it difficult to get goods delivered to the people in need. In this case, prepositioning is applied in some high disaster possibility areas to minimize the interruption of goods and services flow during times of disaster. The four critical stages of resilience in humanitarian logistics are preparedness, training, response and recovery. Pre-positioning of emergency supplies is a key part of the preparedness activities aimed to reduce the response time. It provides numerous benefits to relief organizations (Rawls and Turnquist 2012). In the response stage, disaster assessment tools are activated and disaster mitigation programs are conducted. For further improving the response time, a fast and accurate analysis tool is necessary which in the long term can further help to shorten the recovery time. The ability to quickly respond is essential in mitigating long-term negative effects of a disaster. Inadequate and rash responding to crises due to a lack of coordination and planning can amplify the difficulties faced in responding to catastrophic events. When a disruption happens, it is a challenge to call for field study experts within a short time. Under this kind of condition, developing an emergency analysis tool focusing on resilience and providing a way out for emergency decision making with little information on hand for non-technical staff is in high demand. Table 1 gives an overview of the differences between the EMMA, MIFIRA and HEA response analysis tools.

Table 1: Comparison of different market response analysis tools

<b>Response Analysis Tools</b>	<b>Emergency Market and Mapping Analysis (EMMA)</b>	<b>Market Information and Food Insecurity Response Analysis (MIFIRA)</b>	<b>Household Economic Approach (HEA)</b>
Definition	Emergency market analysis tools which generates rough and quick response guidelines for decision making.	A response analysis tool to evaluate the feasibility of transfer options given market conditions and household circumstances and preferences.	A periodic assessment of the gap between the supply and demand for food aid commodity upon which a decision is made to allow or cut off food aid flow to a certain country.
Focus	To support rapid decision making for a broad range of news	Assess how markets, consumers and traders respond to	Establish floor price and quantity to reduce disincentive

	through market mapping and analysis during sudden-onset emergencies.	transfers and can be used in both chronic and emergency food crises.	effects at a macro level.
Staff Requirement	Non market specialists, requires good analytical skills.	Need specialist staff who are able to work on the problems with limited data at hand.	Require staff with moderate logistics experience, experienced consultant and local staff member.
Shortcoming	It is mainly used for short time response and lack of follow-up/monitoring.	Longer timeframe compared to EMMA. Focuses solely on food market.	It is a supply-side analysis and has not been used in a rapid-onset emergency context.

## 2. EMMA FRAMEWORK

EMMA is a set of tools and guidance for front-line humanitarian staff to utilize during the sudden onset of emergencies to better understand, accommodate and make use of the environment. It is developed to fill the gap between humanitarian and economic recovery communities for more informed decision making. It is adaptable and time sensitive processes are designed to reflect the information constraints and urgency of decision-making. Besides, it can assist in monitoring performance and accessibility of market systems and define the requirements for more detailed future market analysis. It is used under the condition that the background information, time and capacity to analyze existing markets are limited and expert market-analysis capabilities are unavailable to interpret market data. It is suitable for non-market specialists making urgent decisions that are adequate during the sudden onset of a crisis. However, it does not put markets before people.

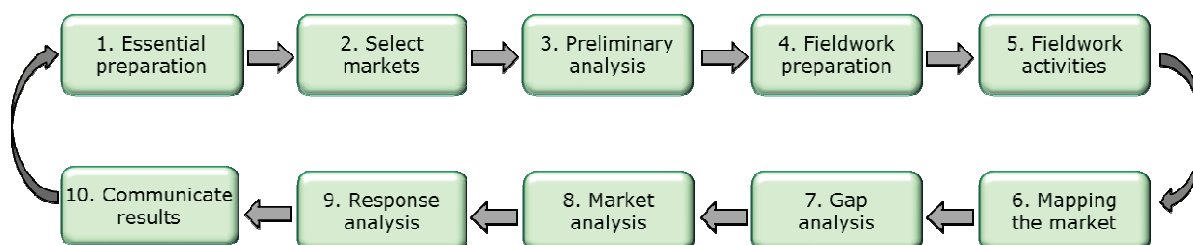


Figure 1: EMMA Framework – An iterative process

There are ten steps in the EMMA analysis as shown in Figure 1. In practice, these steps are flexible and may overlap. It is an iterative process until a good enough solution can be achieved. First, the key market systems are selected based on the chains that affect the largest amount of the targeted population. Once the critical markets are chosen, background research is carried out on them. Interviewing market actors is a key part of market analysis. It includes visiting actors in key locations, enquiring about their current operation and accessing the constraints they face according to the pre-designed surveys. The mapping process includes three key components market environment, key infrastructure and market system actors. The market actors can be wholesalers, consumers, vendors, national producers, importers or food aiders.

### 3. EMMA Analysis Process

As shown in Figure 2, there are three main analyses strands in EMMA. Firstly, gap analysis which is also called people analyses is to identify the people’s uncovered needs, priority and preference through investigating the emergency situation. It is similar to emergency needs assessment. The main difference is that it focuses more on the household’s interactions with market needs. The second analysis is the market system analysis which is to identify the market system’s capabilities and constraints by developing market mapping before and after a crisis. The mapping process includes finding the market’s core value chain, key infrastructure and environment. The last is response analysis which analyzes the pros and cons, feasibility and risk of possible different options of intervention. The three strands support each other and the whole process is iterative until a good enough result can be achieved. Finally, response options and recommendations will be demonstrated to ensure long term stability and quick recovery in the affected region.

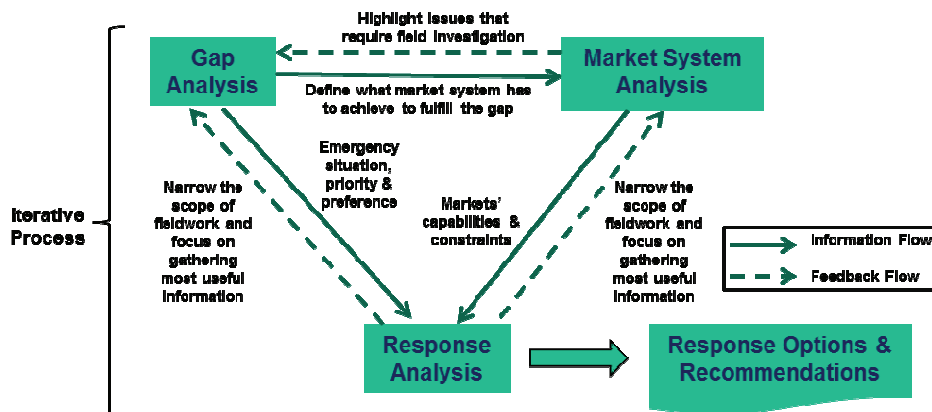


Figure 2: Iterative Analysis Process

#### 4. IMPACT OF EMMA

EMMA makes full use of the market actors' capabilities in order to use humanitarian resources more efficiently and accelerate the process to economic recovery as well as minimizing the dependence on external assistance. It provides guidance for emergency response planning. It is designed to reflect market constraints and to make urgent response decisions in the first few weeks of an emergency. Markets play a vital role in supplying consumer goods to ensure the survival of the targeted population. Mapping and analyzing the markets enable market supply to meet the needs and decide whether cash-based assistance is needed. While EMMA shows great adaptability and flexibility in its implementation, it also faces challenges. Table 2 shows the strengths and challenges when implementing EMMA.

Table 2: Strengths and challenges of EMMA

<b>EMMA Strength/ Characteristics</b>	<b>EMMA Challenges</b>
Its structure combines market, gap and response analysis to produce tailored response suggestions which is easy to use.	It requires strong leadership and analytical skills. Especially for EMMA team leaders, experience in carrying out assessments is necessary.
It can also be used for early recovery and preparedness other than its original objective for emergency response.	Time needed for the assessment is dependent on the availability of existing background information and market system structure.
It is a flexible tool used under the condition of limited resources.	Difficulty in collecting data
It provides donors with reference for necessary response options so as to get funding for the recovery programmes.	

#### 5. CONCLUSION

The EMMA toolkit is formed due to the need for good analysis and understanding of how critical market systems are functioning and disrupted for the people's long term security. It is a user friendly non-market specialist analytical tool under an emergency situation where specialists are hard to locate and resources are limited. It helps to have a broader and more insightful response options. The core logic of EMMA is proven to be successful. EMMA focuses on a few critical markets to help give recommended options for market support

response. The demand versus market capacity information obtained from the EMMA analysis can be used for capacity building project. The focus on a few targeted markets provides more detailed information compared with general market analysis. Despite the powerful impact EMMA can have in sustaining lives and it is not intended to replace the emergency response assessments but they can be carried out simultaneously and integrated into each other.

EMMA grants the most appropriate response and support market functions and environments to address basic urgent needs and provides baseline while seeking for future long term recovery. Market system analysis is the focus of EMMA in order to understand the ability of the market to respond to the crisis and to anticipate the increase in demand. The goal of market analysis is to make optimal use of the capacity of the existing market system and help as many affected households as possible. Close coordination among the private and public agencies and appropriate interventions can help to prevent market distortion and ensure adequate supply at reasonable prices.



# DECONSTRUCTING MODULARITY IN THE CONSTRUCTION INDUSTRY

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## INTRODUCTION

Modular designs and approaches are a useful means for managing complexity (Ethiraj and Levinthal, 2004), and help to rapidly respond to changing customer requirements (Galunic and Eisenhardt, 2001). In essence, modularity involves breaking up a system into discrete chunks, which communicate with each other through standardised interfaces, rules and specifications (Baldwin and Clark, 2000). Schaefer (1999) argues that key challenges for a modular system are finding the appropriate number of modules, design elements, interactions and interfaces. Baldwin and Clark's (2000) seminal work on the role of modularity in the design process traces its origins to the early days of software and computer design. They provide a lengthy discussion on the nature of modularity, suggesting that a key feature is the interdependence within and independence across modules. They argue that there exists 'degrees of connection' and 'gradations of modularity'.

Modularization is a broad concept though, with various interpretations and meanings across research disciplines and market sectors (Cigolini and Castellano, 2002). This article specifically focuses on the construction sector. Supply chains in this industry typically have to cope with project specific requirements, and high levels of customisation as construction companies consult regularly with clients and customers (Schönwitz et al., 2012). One potential strategy for this challenging sector is to shift the decoupling point to enable more standardization and better manage product variety (Gosling and Naim, 2009). However, while the benefits of modularity in the construction industry are conspicuous and there is a growing interest towards and appreciation of modular houses (Bradbury, 2012), there is little consensus or guidelines as a precise understanding of a house building module and its impact on the supply chain (Doran and Giannakis, 2011).

Hence, we aim to answer two questions: 'what is a house building module?' and 'what are the implications for the supply chain?'. Our empirical activities are based on case studies of eight projects, and in answering the research questions our findings are organized into three sections. Firstly, the interpretations of modularity across seven different projects are analysed. Secondly, the range of individual modules identified for the projects are categorized. Thirdly, we present a selection of 'module profiles' and discuss the supply chain implications.

## LITERATURE REVIEW

### Modularity

Modularity is a strategy for efficiently organizing complex processes and products. In general terms, a modular system is composed by modules that are "loosely coupled" (Mikkola, 2006; Schilling, 2000) and that can be "mixed and matched" (Schilling, 2000) thanks to standardized interfaces (Baldwin and Clark, 2000). The concept of modularity has been applied to, among the others, products, organizations and supply chains (Pero et al., 2010). Products can be either 'modular' or 'integral' depending on the allocation of functions to modules (Ulrich, 1995) and on the nature and number of interfaces (Ishii et al., 1995): in a pure modular architecture each module performs only one function and interfaces are standard. Product modularity allows firm to increase product variety while reducing the effects on operational performance coming from product proliferation.

In recent years the role of product modularity has received increasing attention in the literature regarding supply chain management (Salvador et al., 2002). Some of the few studies on the topic (Doran and Giannakis, 2011; Hofman et al., 2009; Voordijk et al., 2006) report that the supply chains of modular housing systems are made up of two kinds of actors: (i) the system architect and integrator, that defines the product architecture and the design rules for the new modular building, and (ii) modules suppliers. Doran and Giannakis (2011) observe that modules suppliers that contribute significantly to the module solution exhibit a high integration, i.e. high willingness to accommodate changes to the modules. Hofman et al. (2009) suggest that the level of integration between the system architect and the modules suppliers is aligned to some features of the module: variety, supplier investment required and supplier knowledge. Additionally, necessary conditions for this shift are (i) the possibility to efficiently transport heavy and big building elements, and (ii) workforce's productivity and quality of the building elements manufactured off site is higher than the corresponding workforce's productivity and quality on site (Cigolini and Castellano, 2002).

Salvador et al. (2002) consider that modularity research may be split into two disciplinary areas: design theory and operations management. Moreover modularity has been found to be a significant design variable in helping to align design and supply chain processes (Pero et al., 2010). From the design perspective, there is the need for certain design rules that enable the designer to configure a house considering the following constraints and requirements. These might include the client's requirements, regulatory requirements or environmental, social and/or economic requirements. Such constraints need to be considered and captured by design rules (Baldwin and Clark 2000). The latter might include design parameter choices, product structure and hierarchy, and potential interconnections between parameters (Baldwin and Clark 2000). From the operations management perspective, modularity has largely been considered as a strategy to increase commonality across different product variants within a product family without incurring in operational inefficiencies (Salvador et al., 2002). As can be seen from the foregoing discussion,

achieving modularity requires a complicated co-ordination of design and operational approaches.

### **Modularity in the construction sector**

Barlow et al. (2003), while analysing the Japanese construction industry, noticed that many companies offer customized buildings coming from pre-assembled modular units, to increase product personalization without incurring in too high costs and lead time. Doran and Giannakis (2011) provide a more extended definition of construction modularity to include a modular approach to design, production and planning. Elsewhere, researchers analyse modularity by focusing on the degree of component independence and interface standardization (Voordijk et al. 2006). This definition is more in line with the traditional definition of product modularity (Ulrich 1995). Modular houses have been characterized as being made up of modular units, built off-site with connections to adjacent units that are completed on site, including the use of standardized interfaces (Hofman et al., 2009).

There is a proliferation of terms associated with modularity in house building in the literature. These include, amongst others, offsite, prefabrication, pre-assembly, modern methods of construction, and industrialized buildings. Gibb and Isack (2003) propose a useful framework to classify offsite production approaches. They identify factory made components and subassemblies, non volumetric pre assembly which do not create usable space, volumetric pre- assembly (fully finished usable space), and modular buildings, which form the structure of the building. Schoenwitz et al. (2012) take more hierarchical view of the product architecture, clustering house elements into categories, components and subcomponents. They highlight the importance of findings the degree of standardization and customization across these hierarchical levels. Given the proliferation of terms, and the various perspectives on modularity, a range of definitions is provided below:

- “a separable component, frequently one that is interchangeable with others, for assembly into units of differing size, complexity, or function” (Dictionary.com, 2013)
- “contains the specifications of a building block and interfaces, as well as considerable functionality compared to the end product” (Björnfot and Stehn, 2004)
- “a unit whose structural elements are powerfully interconnected among themselves and relatively weakly connected to elements in other units” (Baldwin and Clark 2000, p64)
- “the provision of modular solutions constructed off site using modular principles and delivered, installed and commissioned on-site to a pre-determined modular plan” (Doran and Giannakis, 2011)

Using the above definitions, and the foregoing literature review, we specify seven decision parameters for an individual module: size, weight, number of interfaces, number of functions, linkages, subcomponents and structural relevance. They are visualised in figure 1. It is envisaged that each design parameter embodies a potential range, and that the profile across the parameters will have implications for the supply chain, as we will explore in the empirical aspects of the research. It is envisaged that the designer and manufacturer make a collaborative decision as to where along the spectrum each of these variables should lie, based on constraints and customer requirements.

Design Parameter	Range	
<i>Size</i>	Small	Large
<i>Weight</i>	Light	Heavy
<i>Interfaces</i>	Few	Many
<i>Functions</i>	Few	Many
<i>Linkages</i>	Loose	Tight
<i>Subcomponents</i>	Few	Many
<i>Structural Relevance</i>	Low	High

Figure 1: Seven design parameters for a module

## RESEARCH METHODS

The project case studies are situated in Italy, Germany, the UK and Brasil. Within the case studies, we specify 'modules' as the units of analysis (Yin, 2003). In total, the modular approaches in 8 construction projects are investigated, covering primarily residential developments projects. Data was collected through an interview protocol, combining structured and semi structured elements. The protocol was influenced by generic modularity literature, as well as construction specific research. Interviews were carried to capture a range of perspectives, including design and architectural, managing directors, and supply chain management. The interview script was split into a number of headings which included: company overview, project specific details, modules used on the project, processes and supply chain, project phases, production details and performance. Each section probed the use and role of modularity. To anchor the questions, interviewees were encouraged to pick a specific project to focus on. Data was analysed through qualitative coding and thematic analysis, as well as descriptive statistics for quantitative data. The range of projects included in the study are shown in Table 1. As can be seen from the brief descriptions, they are primarily in the residential sector. The projects also differ in scale, including single dwellings to larger scale developments. Projects were chosen with the intention of including those with a known interest in modular techniques, a willingness to participate in a research programme, and to cover a range of project types and perspectives.

Project	Interviewee	Brief Description	Approx Value (Euros) / Duration	Location
1	Managing Director	Office with 3 floors	7 million / 27 months	Italy
2	Managing Director	Two residential towers. 14 floors	8.5 million	Brasil
3	Designer/Architect	Two residential towers. 18 and 24 floors	-	Brasil
4	Managing Director	Wood structure house	1 million	Italy
5	Managing Director	Luxury Residential house	750000	Germany
6	Designer/Architect	Oak Beam House	500000 / 4 months	UK
7	Designer/Architect	94 terraced house development	13.7 million / 14 months	UK
8	Designer/Architect	Student Halls of Residence	30.7 million / 12 Months	UK

Table 1: Overview of Projects

## **CASE FINDINGS**

### **Definitions of modularity**

Figure 2 shows some direct quotations from the interviewees in relation to their perception of modularity, which was probed in the initial section of the interview protocol. The quotes can be clustered into three areas for discussion: the hierarchy of a module, the interfaces and connections, and the degree of work done offsite. The hierarchical breakdown relates to the breakdown of the module itself. Definitions clustered into those that considered a module as a group of components, and those that had a scheme for breaking down the hierarchy of a building. For example, in the case of project 6 building elements were broken into 3 levels, including primary, secondary and attributes. The degree of offsite manufacturing was a key theme that emerged from the interviews. Two approaches were frequently referred to. Either modules tend towards fully finished units completely factory made, or they may be partially finished with careful thought given to assembly on site. The final cluster identified relates to interfaces. As can be seen by the quotes displayed in figure 1, many interviewees referred to the use of standard interfaces and connections for modules.

### **Categorization of modules identified**

During the study, a range of modules were identified across the projects chosen. An overview of modules identified is given in figure 3. It shows modules identified with a corresponding project number. The diversity in these modules is noteworthy, and as a result we have categorized them into different groups. The categories are influenced by Gibb and Isack (2003), Gibb and Pendleton (2006), Schoenwitz et al (2012). Firstly, there is *Developmental Segmentation* (layer one in figure 2). This category encompasses large repeatable segments that repeat across a development. They have a structure and can stand alone, and can be the main chunks of which a development project is composed of. Therefore, they are usually associated with more than one function, e.g. both entrance, bedroom and toilet. For example, project 7 is divided into 5 segments which repeat throughout the whole project.

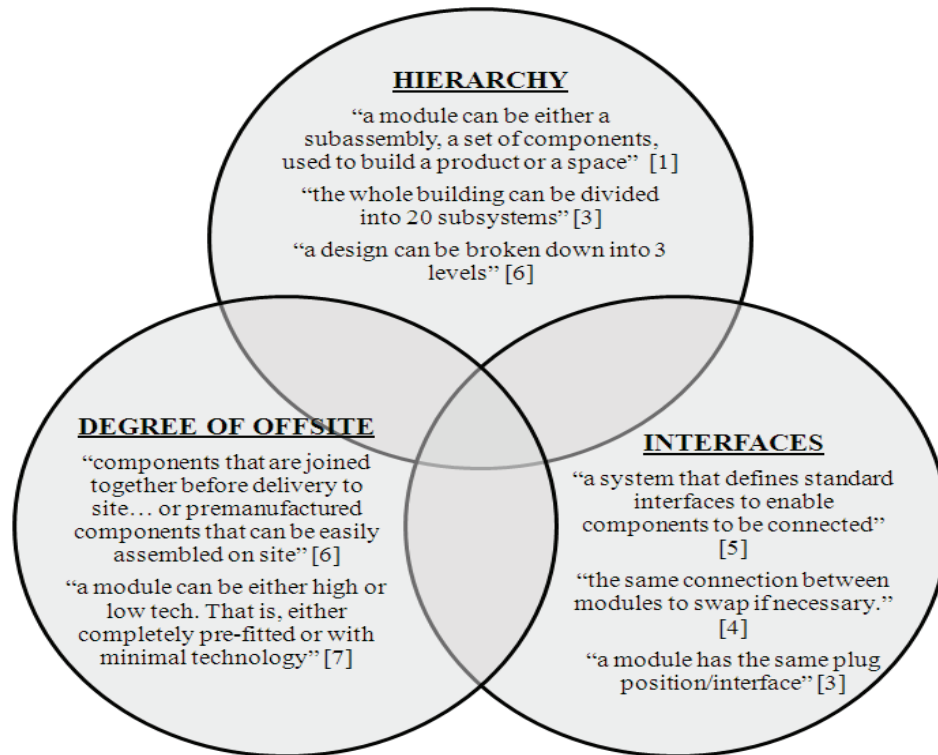


Figure 2: Clustering of modularity definitions

The second grouping (layer 2 in figure 3) refers to *Volumetric Units*. These are building elements that create usable space that, in most of the cases, are completely finished in the factory. They are normally connected to a specific function, e.g. entrance or bedroom. An example here would be room pods manufactured fully furnished for project 8. We refer to the third category as *Non Structural Subassemblies*. These can be the systems used to provide the services needed to run the building, and are used by some or all the other units of the building. They can be fully or partially assembled off site and therefore already integrated in the bigger building elements. Toilet and fire safety systems are a good example of this category. The final category is labeled *Structural Subassemblies*. These are fully or partially finished building elements that form part of larger structural elements assembled on site. Wall, floor and roof elements are good examples of this category.

It is noteworthy that the proposed categories resemble the categories proposed by Gibb and Isack (2003). However, differently from Gibb and Isack (2003), our focus is not only on prefabrication and preassembly, but we aim to provide wider definitions of the modules, that include a range of perspectives. Our categories were indeed derived from interviewees to both managing directors, therefore more interested in manufacturing aspects, and designers and architects. This allows us to understand, for instance, that also designers and architects interpret the concept of modularity by representing the building as done by repeatable segments, independently from where there will be actually assembled (on site/off site), thus we were able to enlarge the scope of the definition of “modular building” to “Developmental Segmentation”, and the other definitions as well. It can be noticed that hierarchical relationships between categories of modules can be found, e.g. a System or a

Volumetric Unit can be composed of Structural Subassemblies. Based on our interviews results, we observed that a modular building can be constituted by modules belonging to all the proposed categories, therefore defining a category “modular building”, as Gibb and Isack (2003) did, would be too simplistic for the aim of our work. Our definitions can be therefore used to identify the modules in a building, being the definitions enough generic to constitute a common ground for both architects and operations managers, and the relationships between modules. Then how much of each module is pre-assembled can be defined.

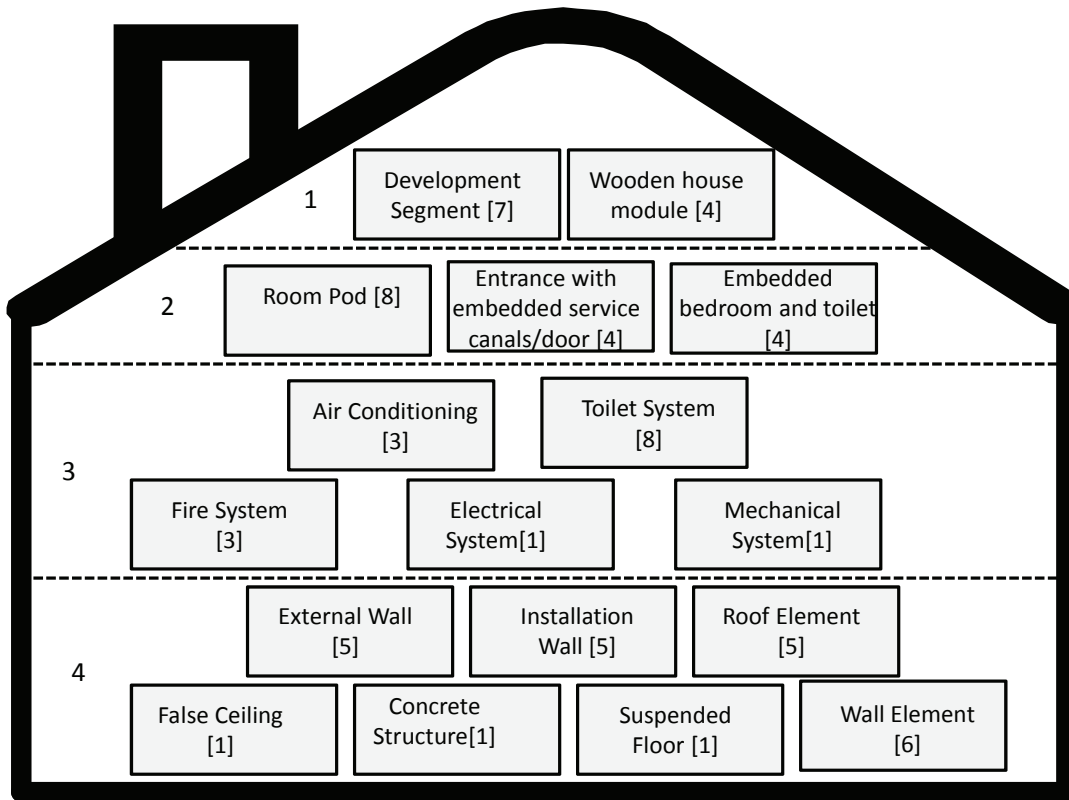


Figure 3: Overview of modules

### Module Profiles with Supply Chain Implications

The final part of this paper analyses individual modules, and their impact on supply chain and logistics. To this end, we have developed a range of module profiles. The profiles make use of the design parameters identified in the literature review. Figure 4 gives four examples of such profiles. Each has been ranked along the range of design parameter continuums to give a more refined breakdown of the characteristics of each module. The supply chain implications are then illustrated in the bottom right hand corner of each profile. We have chosen an illustrative example profile from each of the levels described and depicted in figure 3. The first is the external wall module for project 5, which falls under the category of *structural subassembly*. The photo shows how it is preassembled in the factory. The external wall modules are manufactured off site. Furthermore these are entirely customized. Depending on the appropriate wall there can be a whole variety of interfaces and linkages for sanitary, electrics, heating and other walls. The modules consist of many

different sub-components as for example post and beams, glazing, doors and sockets. Once finalized, the modules are lifted on trailers which are then taken to site. On site a crane is needed to lift the modules in position. Connection of the modules is then done fairly quickly which means that the outer shell of a 300m<sup>2</sup> home can be erected within one day.


The second, immediately beneath the external wall, is a wooden house module used in project 4. We have categorized this as a *developmental segment*. The wooden house modules are fully realized off site. Transport is a very critical matter: truck renting is expensive and there are strict regulation regarding transportation, thus limiting the areas that can be served with these kinds of buildings. Placing the module on site is done using a crane, then and all the pipe and canals are connected This activity takes sometimes less than one week to be completed. This is repeated across the development being undertaken. Moving to the right on figure 4, a profile for a room pod in project 8 can be observed. This falls under the category of *Volumetric Preassembled Unit*. The room pod is factory made to a standardized specification. A standard steel room frame is connected in the factory, and insulation, shower unit, furniture and services are also fitted. Finally the windows are installed. These are then delivered to site in a specific sequence, according to a template developed jointly between the architect and the manufacturer. They are connected via steel plates on site. The final profile in figure 4, shown in the top right corner is *non structural preassembly*. This toilet system, used in project 5, is connected to other modules and manufactured offsite.

Design Parameter	External Wall Module	
Size	Small ●	Large ●
Weight	Light ●	Heavy ●
Interfaces	Few ●	Many ●
Functions	Few ●	Many ●
Linkages	Loose ●	Tight ●
Subcomponents	Few ●	Many ●
Structural Relevance	Low ●	High ●


  

Design Parameter	Toilet System	
Size	Small ●	Large ●
Weight	Light ●	Heavy ●
Interfaces	Few ●	Many ●
Functions	Few ●	Many ●
Linkages	Loose ●	Tight ●
Subcomponents	Few ●	Many ●
Structural Relevance	Low ●	High ●

	<p><b>Implications for Operations</b></p> <ul style="list-style-type: none"> <li>• Manufacturing Complexity: Moderate</li> <li>• Transportation: Some Challenges</li> <li>• Site fitting: Easy</li> <li>• Handling: Easy</li> </ul>
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	<p><b>Implications for Operations</b></p> <ul style="list-style-type: none"> <li>• Manufacturing Complexity: Moderate</li> <li>• Transportation: Easy</li> <li>• Site fitting: Easy</li> <li>• Handling: Easy</li> </ul>
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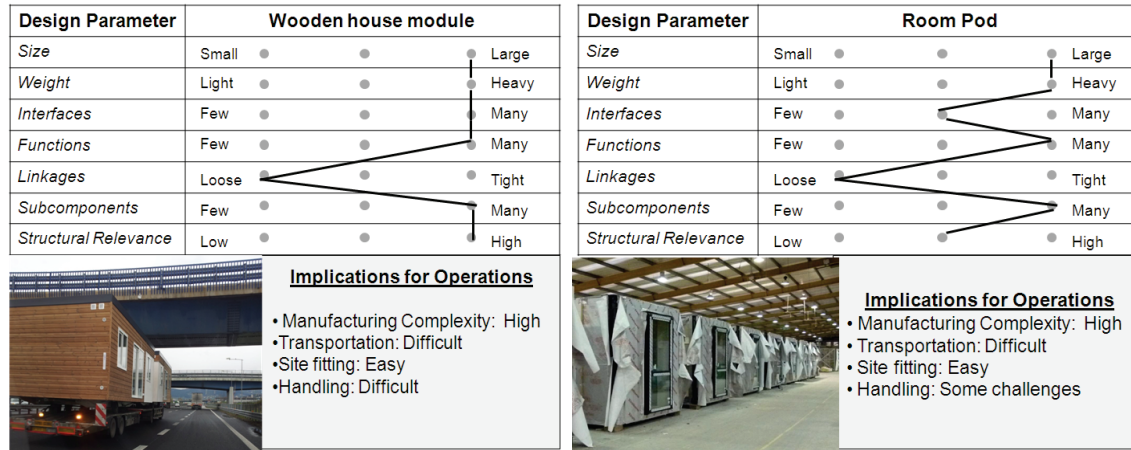


Figure 4: Selection of module profiles with supply chain implications

## CONCLUSIONS

This paper has empirically investigated the use of modularity in 8 different construction projects, situated in Italy, Germany, the UK and Brasil. At the outset we asked 'what is a house building module?' and 'what are the implications for the supply chain?'. In answering these questions, seven design parameters for an individual module were developed and investigated empirically, and insight is given in terms of interpretation and use of modularity in the construction sector. Our findings can be summarized as follows. Firstly, the interpretation of modularity clusters under the headings of hierarchy, interfaces and degree of offsite manufacture. Secondly, the modules identified across the range of projects can be arranged in a hierarchy, to show that modularity operates at different levels within the product architecture of a building. Finally, a number of decision domains for a module were identified, and used to develop a selection of module profiles, which offer insight into the supply chain implications. The paper sets out practical decision domains for practitioners to consider a module, and it's implications, in the construction industry. Due to the nature of the case research, care must be taken in generalizing results across market sectors and industries.

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# A FUZZY MULTI-OBJECTIVE MODEL FOR RELIEF OPERATIONS

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## ABSTRACT

This paper provides a fuzzy multi-objective decision model to determine how relief items should be optimally distributed to disaster affected regions. Specifically, we evaluate the selection of the supply depots and their associated supply quantities to satisfy the multiple managerial objectives of urgency, cost, and quality as equitably as possible. While relief logistics modeling exists in the literature, tri-criteria or more objectives are under-represented. Our paper is the first work in relief logistics to use at least three criteria in modeling relief activity in a structured way, which is of particular value to academia and practice, thus providing a realistic reference for NGOs in relief logistics planning.

**Keywords:** Relief Supply Chain Management, Emergency Logistics, MCDM, Model

## 1. Introduction

Disasters can strike anywhere, at any time and with unpredictable magnitude, bringing about suffering, loss of life, livelihood and shelter for millions of people. In recent times, climate change, population imbalance and urbanization have contributed to natural disasters becoming deadlier and costlier, especially in Asia. When a disaster strikes, relief agencies play a pivotal role in assessing the damage, raising an international appeal for aid, and providing relief by creating an emergency logistics corridor(s) for critical rescue and relief supply to enter the intended destination sites.

Relief logistics, like commercial logistics, is predicated on the ability to deliver to the desired destination within a desired time window, without violating the constraints set on it (Wassenhove, 2006). These constraints include regulatory reporting and clearance for medical devices, local feedstock of supplies, and budget. A few key differences exist between these two forms of logistics. First, for obvious reasons, there is no traditional revenue maximisation for relief logistics. In lieu of this, there is instead the "lives saved" optimisation. Second, there is cost minimisation but this is usually internal to the NGO implementing the relief operations. Third, there is the minimisation of the time to relief site. In commercial speak, this is akin to the notion of speed to market. Apart from these operational objectives, the usual parameters apply, namely,

- The type, volumes and locations of the relief goods needed.
- The volumes and locations of relief goods available both from outside the affected area, and from local sources found in the vicinity of the affected area.
- The availability (and mode) of transport into the disaster zone and the associated planned/scheduled arrivals of the relief goods.
- Warehouse availability (including that from government, relief agency, and private sector) within the affected area, for temporary storage.
- Transport availability (and mode) to cover the 'last mile' to the recipients.
- Any special handling requirements such as the need for 'cold chains' to support the

movement of certain medicine, medical equipment, food, and so on.

In the absence of a profit motive, the relief supply chain's objective is thus to balance cost and speed while saving lives, without compromising on security, quality, and safety. We envisage the relief supply chain as comprising several stages of aid disbursement: ramp-up, sustain, and ramp-down. The achievement of these objectives varies across the different stages of aid disbursement. In the 'ramp-up' stage, agencies may choose to air-lift the relief supply at a faster speed albeit at a higher cost. In the next stages of 'sustain' and 'ramp-down', the focus may shift from bringing in relief supply fast, to combining the different modes of transport to achieve a lower cost especially once it is past the critical 72 hours. Both demand and supply are uncertain in the relief supply chain, as a disaster can strike with any magnitude and the flow of supplies is unknown a priori. While a relief supply chain differs from a commercial supply chain in several aspects, the need for effective supply chain planning and co-ordination remains unchanged. However, the time-to-market requirement becomes stricter as lives are involved (e.g. the Tangshan earthquake of 1976, the Aceh tsunami of 2004, and the Fukushima incident of 2011). Also, while disasters due to natural calamities, wars, and political strife are on the rise across the world especially in Asia and relief aid agencies are playing an even greater role with larger relief and response budgets, there is much criticism and concern about the effectiveness of the relief aid community.

Indeed, almost 60-80% of the operating expense incurred in a relief operation is due to logistics and supply chain activities (Wassenhove, 2006). There is thus an imperative to develop and deploy (in short, borrow) the mathematical tools and techniques practised by a commercial supply chain to relief supply chains for better resource optimization and supply chain operations planning and orchestration. There is a lack of such work in the literature (Atlay and Green, 2006). Hence, we seek to develop a suitable multi-criteria decision making tool to improve the effectiveness and efficiency of relief operations. In the ideal, the model should be able to decide how much to supply, from which supply point, keeping in mind the constraints related to infrastructure, seasonality, demand, and availability, taking into consideration practicalities of demand variations, supply routes, site-specific constraints, transport mode choice, and the various phases of the relief operations.

The rest of the paper is set as follows. Section 2 presents the model, followed by the numerical results, and sensitivity analysis. Some concluding remarks complete the paper.

## **2. Model Development**

Using the standard notations, we develop the fuzzy multiple objective programming model (FOMP) for 2 scenarios (the notations and definitions are available from the authors).

### **Scenario 1: NGO owns relief items**

Medical devices which can cover thousands of items (from pacemakers to wheelchairs), depending on their classification, typically have to be registered with the relevant host country's health authority before they can be used in the host country. One reason for this is that some of the medical devices are high-risk products. The registration process can be tedious, taking as long as 16 months for the approval to be given, and applies uniformly

irrespective of whether it is a quantity of one or many, and whether it is for an exhibition or emergency usage. In addition, the process applies irrespective of whether the device has already been cleared by the health authorities in the neighbouring countries. This tedious regulatory process of registration can impede the flow of the relief supply chain especially in relief operations. Hence, NGOs are interested in pre-positioning their critical inventory items for relief operations in certain disaster prone locations. In such a situation, the NGO has to bear the responsibility of owning the stock, subject to budgetary and capacity constraints. Having pre-positioned stocks from an NGO warehouse allows them to respond promptly to disasters as shown in the Indonesian Merapi volcano eruption on 25 October 2010.

In this scenario, the NGO owns the relief items at supply depots located in different countries. Each supply depot has a fixed capacity to hold certain relief items. When a disaster occurs, the relief distribution network will be activated to deliver the necessary relief items to the affected regions. Since the relief items are owned by the NGO, they can be authorized for quick delivery without having to go through the permission grant process. However, certain items such as medicine and food supply may require permission from the local government of the affected regions (as was the case with Cyclone Nargis that caused the worst natural disaster in the recorded history of Burma on May 2, 2008, causing catastrophic destruction and at least 138,000 fatalities). Since severe injuries, disease, and food shortages often accompany a disaster, the relief items must arrive at the affected region within the 72-hour golden window so that medical treatment can be employed during this acute phase. Thus, it is critical to determine which supply depots to provide necessary relief items at what quantities so that these items can be delivered on time to alleviate the suffering of the vulnerable people in the affected regions. In addition, since the relief items are held by the NGO, it is also vital to determine the holding capacity for each relief item.

### Model (M405C)

We develop the model as follows, using four objectives of transport, response time, inventory, and degree of urgency.

Transportation cost minimization  $Min Z_1 \cong \sum_k \sum_i \sum_j CT_{ij}^k X_{ij}^k$

Response time minimization  $Min Z_2 \cong \sum_k \sum_i \sum_j T_{ij}^k Y_{ij}^k + \sum_k \sum_j f_j^k t_j^k Y_{ij}^k$

Inventory cost minimization  $Min Z_3 \cong \sum_k \sum_i H_i^k Q_i^k$

Degree of urgency maximization  $Max Z_4 \cong \sum_k \sum_j U_j^k Y_{ij}^k$

*Subject to*

$$\sum_i X_{ij}^k \cong D_j^k \quad \text{for all } j \text{ and } k \quad \text{(Fuzzy demand constraint)}$$

$$T_{ij}^k Y_{ij}^k + f_j^k t_j^k Y_{ij}^k \leq W \quad \text{for all } i, j \text{ and } k \quad \text{(} W \text{ hours window constraint)}$$

$$\sum_k \sum_i CT_{ij}^k X_{ij}^k + \sum_i H_i^k Q_i^k \leq B_j \quad \text{for all } j \quad \text{(Budget constraint)}$$

$$T_{ij}^k Y_{ij}^k + f_j^k t_j^k Y_{ij}^k \leq P^k \quad \text{for all } i, j \text{ and } k \quad \text{(Perishability constraint)}$$

$$\sum_j X_{ij}^k \leq Q_i^k \quad \text{for all } i \text{ and } k \quad \text{(Capacity constraint)}$$

## Scenario 2: Donor countries own relief items

In this scenario, the relief items are owned by the private or public organizations of the donor countries. The relief items need to be granted permission for export to the affected regions located in the recipient countries. The time to obtain permission from the governments where the supply depots are located will delay the delivery process and hence needs to be considered in the delivery plan. Further, as the relief items are not owned by the NGO, they need to be purchased from the owner of the supply depots and hence a purchasing cost is incurred. We now include these factors into the basic model, M4O5C, as shown.

### Model (M3O5C)

$$\text{Transportation cost minimization} \quad \text{Min } Z_1 \cong \sum_k \sum_i \sum_j CT_{ij}^k X_{ij}^k$$

$$\text{Response time minimization} \quad \text{Min } Z_2 \cong \sum_k \sum_i \sum_j T_{ij}^k Y_{ij}^k + \sum_k \sum_i f_i^k t_i^k Y_{ij}^k + \sum_k \sum_j f_j^k t_j^k Y_{ij}^k$$

$$\text{Degree of urgency maximization} \quad \text{Max } Z_3 \cong \sum_k \sum_j U_j^k Y_{ij}^k$$

subject to

$$\sum_i X_{ij}^k \cong D_j^k \quad \text{for all } j \text{ and } k \quad \text{(Fuzzy demand constraint)}$$

$$T_{ij}^k Y_{ij}^k + f_i^k t_i^k Y_{ij}^k + f_j^k t_j^k Y_{ij}^k \leq W \quad \text{for all } i, j \text{ and } k \quad \text{(} W \text{ hours window constraint)}$$

$$\sum_k \sum_i CT_{ij}^k X_{ij}^k + \sum_i C_i^k X_{ij}^k \leq B_j \quad \text{for all } j \quad (\text{Budget constraint})$$

$$T_{ij}^k Y_{ij}^k + f_i^k t_i^k Y_{ij}^k + f_j^k t_j^k Y_{ij}^k \leq P^k \quad \text{for all } i, j \text{ and } k \quad (\text{Perishability constraint})$$

$$\sum_j X_{ij}^k \leq Q_i^k \quad \text{for all } i \text{ and } k \quad (\text{Capacity constraint})$$

## Numerical example

An illustrative example is given to demonstrate the implementation of the proposed models. Assuming an earthquake hits Region R, causing widespread destruction and loss of life. Preliminary damage report records 85,000 people dead and another 40,000 missing. Poor infrastructure and limited communication networks further aggravate the catastrophe. In all, about 1.2 million people are affected. To accommodate the refugees, four camps (East, West, South, and North) are established on higher ground near the quake site. However, the "optimum" 72-hour golden window for relief effectiveness holds. Four NGOs (three from Asia and one from Europe) have promised to offer relief supplies to support the refugee camps. Most of the relief items have to be imported but the central government requests that all relief cargo must be inspected and cleared before they can be released. The lead time for delivery from the entry port to the region is 5 hours if the relief items are transported by rail.

Relief items are categorized into food, medicine, hygiene, and basic comfort. Food items include hardy biscuits, milk powder, flour, and rice. Medicine is in the form of syrup, tablets, vaccines, antibiotics, and ointment. Hygiene items usually include water purification tablets, sanitary towels, and sheets. Non-food items may contain personal kits such as soap, clothes, and blankets. Each category of items will be needed with different degrees of urgency due to its capability to reduce the impact of lives lost and financial loss. Also, the perishability for each item category differs due to its nature and the storage environment without refrigeration. It is estimated that food items will perish within 10 days of leaving the depots; 7 for medicinal items, 30 for hygiene kits, and 100 for non-food items respectively. The items have been prepared and stored in the supply depots close to the NGOs and will be shipped to the relief effort on demand. Each depot may store various quantities for each relief item category according to their inventory policy. Thus, different inventory costs will be incurred for each supply depot. It is estimated that approximately 300,000 kits of food items, 100,000 medicinal kits, 150,000 hygiene kits, and 80,000 packs of non-food items are needed. Table 1 shows the fuzzy demand breakdown for the items requested by each camp.

Since the supply depots are sited in different locations, different transportation cost and delivery times are incurred. Table 2 shows the transportation cost and delivery time to the entry port. In addition, the unit cost of a relief item from each category and its associated supply capacity if they must be purchased from private or public organizations of the donor countries are shown in Table 3. In case the relief items are owned by the NGOs,

the unit holding cost for each category from each NGO is presented in Table 4. In addition, a minimum of 5,000 units of items on each item category is required for each supply depot once donation to a camp is planned.

For food and medical supply items, permission needs to be applied and granted by the Custom administration where the NGO is located and the local government of the affected region before they can be transported. The time taken to obtain permission from the Customs agency of the host country is 12 hours for AsiaCare, 8 for AsiaHelp, 15 for Asia Humane, and 6 for EuropeAid. It will take 24 hours for the local government of the affected region to grant permission. Due to the various degrees of damage and living condition, each camp has different needs of the relief items. Table 5 shows the degree of urgency (from 1 to 5 based on how badly it is needed; 1= none, 5= most) for each item in each camp. The budget is set at US \$30 million for East camp, 20 for West, 10 for South, and 10 for North respectively.

The solution of the proposed model is processed as follows.

*Step 1:* Develop the FMOP based on the information described above.

*Step 2:* Solve as a single objective function model utilizing Zimmermann's (1978) max-min approach for each objective function. For Scenario 1, the upper and lower bounds for each fuzzy objective function value are  $(Z_1, Z_2, Z_3, Z_4) = (\{26,692,000, 8,859,000\}, \{3,388, 704\}, \{8,018,500, 514,520\}, \{200, 52\})$ . For Scenario 2, they are  $(Z_1, Z_2, Z_3) = (\{15,919,500, 10,958,000\}, \{3,784, 1,120\}, \{188, 56\})$ .

*Step 3:* Find the respective membership functions for the fuzzy objective functions. Tables 6 and 7 show the membership functions given by the upper and lower bounds of the objective function values for Scenarios 1 and 2 obtained in step 2.

Equations (1) and (2) give the membership functions  $\mu_i(x_i)$  for the fuzzy maximization and minimization objective functions respectively where  $L_1, L_2,$  and  $L_3$  denote the lower bounds for the three fuzzy objective functions, and  $U_1, U_2,$  and  $U_3$  are the upper bounds.

*Step 4:* Defuzzicate the fuzzy demand constraints using a beta probability distribution.

*Step 5:* Reformulate and solve the modified FMOP model as a single objective crisp model using the results obtained from Steps 2 to 4.

A weighted crisp single objective model comprising  $K$  objectives as proposed by Amid et al. (2006) is implemented to solve the FMOP model, where  $\lambda_k$  denotes the achievement level of the  $k^{th}$  objective.

Scenario 1 assumes that the executive of the relief operations has determined that the decision preference for the four objective functions are weighted as 0.15, 0.3, 0.15, and 0.4 respectively. For Scenario 2, the weights for the three objective functions are 0.2, 0.3, and 0.5 respectively. It is noted that the objective to maximize the degree of urgency is considered most important. Tables 8 and 9 present the results of the modified FMOP for each scenario. Table 8 shows that the degrees of achievement of the cost-minimization objectives ( $\lambda_1$  and  $\lambda_3$ ) are greater than the achievement levels of the other two objectives



( $\lambda_2$  and  $\lambda_4$ ) even though objectives 2 and 4 have greater weights. The results suggest that, similar to the private sector, the NGOs need to consider cost issues when planning logistics operations due to budget limitations. In addition, the achievement level of the urgency maximization objective ( $\lambda_4$ ) is greater than the level of response time minimization ( $\lambda_2$ ). This may be due to the NGO of the rescue effort focusing more on sending the most needed goods to the affected region.

In Scenario 1, AsiaCare provides the most quantity on all four relief items since it has the lowest cost in transportation and inventory holding even though the delivery time needed is slightly longer than its Asian counterparts. EuroAid, on the other hand, offers the least help due to the high cost and longer delivery time required. Since capacity in this scenario is finite, AsiaCare should carry more stock than the other NGOs to prepare for future relief operations. The results show that  $\lambda_4$  is greater than the level of the other two objectives. This result agrees with the decision preference that the public expects the NGOs to react to a rescue operation.  $\lambda_2$  remains as the least important, suggesting that as long as the relief goods can be distributed to the needed regions, time is less important than the money spent for the operation.

In Scenario 2, the NGO's supply depot has a supply capacity. AsiaCare uses up all of its capacity in food, medical, hygiene items due to the low transportation and purchasing costs. It is noted that EuroAid cannot not provide any medical supply given its inability to meet the 72-hours time window due to the extra time required to obtain export permission.

## **Sensitivity Analysis**

Sensitivity analysis is conducted to study the impact of delivery time in the affected regions on the performance of the relief operations. The impact is examined by varying the delivery time to compute the associated degree of achievement for each objective function. The results of the sensitivity analysis for each scenario are shown in Tables 10 and 11 respectively while Figures 1 to 7 highlight the relationship between delivery time and  $\lambda_i$ . Figure 1 shows a convex relationship between delivery time and  $\lambda_1$  for Scenario 1, suggesting that as delivery time increases, transport cost will initially increase too. However, as delivery time increases to a certain level, some supply depots may not be able to meet the time window and hence supply depots with cheaper transport cost are selected to provide the relief items. Figures 2 and 3 demonstrate a similar relationship between delivery time, and  $\lambda_2$  and  $\lambda_3$ . Both  $\lambda_2$  and  $\lambda_3$  first increase and then remain stable before increasing again when delivery time increases to a certain level. As the delivery time increases, supply depots with shorter delivery times are favored more for the relief operations. Likewise, these supply depots with shorter delivery times may carry more stock. Figure 4 shows that  $\lambda_4$  decreases as delivery time increases, i.e. a longer delivery time hampers the efficiency of relief operations.

As for Scenario 2, Figures 5 and 6 show a similar relationship between delivery time (only up to 12 hours longer due to the infeasibility of longer hours), and  $\lambda_1$  and  $\lambda_2$ . Unlike the convex relationship found in Scenario 1,  $\lambda_1$  remains the same at first and increases as

delivery time increases to a certain level. Figure 7 is similar to Figure 4 on delivery time and  $\lambda_4$ .

## **Conclusion**

Academia and practice need to work closely to co-design and adapt relief logistics programs for a global environment amidst greater social uncertainty and environmental severity. This will help to shorten the last mile and efficiently deliver for rescue and relief efforts. Our model demonstrates the capability of making multi-objective and multi-attribute decisions to determine the appropriate supply depots and supply quantities for relief operations. While relief logistics modeling exists in the literature (Kunz and Reiner, 2012), tri-criteria or more objectives are under-represented. Our paper is the first work in relief logistics to use at least three criteria in modeling relief activity in a structured way, thus providing a realistic reference for NGOs in effective relief logistics planning. Due to the limitation of space, all Tables, Figures, and References from the conference version of the paper have been removed.

# **ALIGNING SUPPLY CHAIN STRUCTURES TO CUSTOMER PREFERENCES IN PREFABRICATED HOUSE BUILDING**

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## **INTRODUCTION**

There is a growing demand by potential buyers to individualise products. Pine (1993) has been one of the first researchers to recommend Mass Customization as a business strategy to satisfy individual needs with mass production efficiency. As a consequence, customer integration into the design and production process has become a popular business strategy. However, it is vital that companies opting to implement mass customisation develop an appropriate infrastructure considering three main aspects: time to market, variety and economy of scale (Tseng and Jiao, 1998). Typically, house building supply chains have to cope with customer specific requirements due to a high degree of customer involvement (Gosling and Naim, 2009) which increases the need for appropriate order fulfilment strategies. In this regard the house building industry adopted strategies found in other manufacturing environments (Barlow et al, 2003). This resulted in a range of potential supply chain structures providing different levels of customisation and an increased logistical effort due to smaller quantities, higher product variety, and variable demand rates (Ahlström and Westbrook, 1999).

Fisher (1997) denotes that the root cause for many supply chain problems is a mismatch between the type of product and the type of supply chain. Hence, a nescience of customer preferences on the lowest level of the product architecture will influence the supply chain performance in a negative way. On the contrary realigning supply and product strategies properly will result in remarkable competitive advantage (Fisher, 1997). Hence, it is important to align the supply chain strategy appropriately as only then can the business strategy be operationalised and supported effectively. However, only few studies have measured and analysed customer preferences in the house building industry in order to create a basis for the industries' customisation efforts.

A case study enabled the development of a view of the house as a system of components resulting in a product architecture matrix consisting of components, sub-components and attributes. An analysis determined the customisability of each item. Following this an online customer preference measurement was conducted using a modified AHP approach, structured around the product architecture matrix.

Through a combination of the case company's product component hierarchy and the results of the preference measurement survey mismatches between the choice offered and customer requirements are identified. Thereby opportunities to improve strategic alignment and to remove options that are offered but not appreciated by customers are highlighted. It is established that buyer preferences are rather functional than design-oriented.

Hence, it is the aim of this study to answer the following research questions. Firstly, 'what relevance does a product architecture have for the provision of a customised product?'. Secondly, 'how can customer preferences be measured and aligned to what is offered in terms of customisation?'.

## **LITERATURE REVIEW**

### **Mass customisation in the house building industry**

The house building industry is very important for any economy as it provides employment on many different levels (Groak, 1993). However, it is a complex and difficult sector

composed of a variety of people, plant, materials, locations, new technology and knowledge of the law and regulations. In a traditional building process, the house was erected on site with the supply chain aligned to accommodate this. Good project management and precise planning was required to be able to cope with such a complex process.

Hence, simplification of the on-site processes was required. One of the countermeasures was to try and prefabricate houses or parts of the house in an off-site factory environment taking the car manufacturing sector as ideal. At the beginning this was exposed to heavy criticism: "... [this interest in the car analogy] probably appealed to those who prefer walking around in a warm, dry factory to struggling across a building site on a cold damp evening." (Groak, 1996, p. 137). Other researchers (e. g. Gann, 1996) agreed with this view and issued a warning because from their point of view there are clear limitations to which manufacturing systems derived from the car industry can be applied to assemble complex customised buildings.

But there were also researchers who believed in the application of car manufacturing ideas in the house building sector. Gibb (2001) for example states that there are lessons to be learnt by house builders from much of the manufacturing sector and identifies several issues from the car manufacturing sector which he believes will improve the status of the house building industry.

As presented by Towill (2001), Japanese companies have successfully implemented manufacturing principles derived from the car industry in order to produce attractive, affordable and above all customised houses which are clearly aimed at the self build market. They managed to achieve a trade off between the need of economies of scale (i.e. production of standardised parts) to increase profit margins and economies of scope in order to give the customer enough flexibility to get full satisfaction. In this regard, clever product architecture is vital and can give the impression of a fully customised house although in reality it is standard procedure in the production as demanded by Gibb (2001).

In 2003, Naim and Barlow exploited the 'leagility' idea and specifically map it on the customised housing industry. Through case studies and a conceptual model they show that by combining the lean and agile paradigms in a specified way total value can be delivered to the customer. Barlow et al (2003) go on to exploit both the 'leagile' and Lampel and Mintzberg (1996) models in a house building context. They report on various Japanese house builders who are all in off-site manufacture based industry and supply customised homes which are preassembled from standardised components or modular systems. Various generic supply chain models are presented which are able to support mass customisation.

### **Product and supply chain strategy alignment in house building supply chains**

Customer satisfaction can only be achieved if the degree of choice offered matches customer requirements. If customers are offered too much choice there is a risk of confusion rather than satisfaction (Huffman and Kahn, 1998). If too few options are offered to customers they may decide to buy a different product. Hence, customers do not want a lot of options per se. They only want the options that meet their requirements and needs.

A number of studies confirmed that there exists an opportunity to enhance customer satisfaction and increase market penetration if houses meet expectations and needs of customers more closely (Barlow, 1993; Gann, 1996; Barlow et al, 2003; Ozaki, 2003; Hofman et al, 2006; Leishman and Warren, 2006). However, the majority of these approaches concentrated on the building level rather than on the component or even attribute level. If choice is offered on all levels, this over-simplifies the analysis considerably, links marketing and operations on a superficial level and finally leads to mismatches between products and supply chain structures (Schoenwitz et al, 2012).

An important element to consider when manufacturing mass customised products is the Customer order decoupling point (CODP). It can be used in structuring and configuring the supply chain so that total value can be delivered to the end customer (Naim, 1999). Olhager (2003) defines the CODP to be the point in the supply chain where the product is linked to a

specific customer order. In other words the CODP determines the point where customer choice actually penetrates the supply chain. Therefore it is a powerful tool in defining the right combination of efficiency.

Whilst some authors confirm that it is difficult to identify one single CODP in a supply chain (Wikner and Rudberg, 2005; Gosling et al, 2007; Wong et al, 2009) there are hardly any empirical studies researching the existence of multiple CODP.

**METHOD**

This study is based on empirical evidence drawn from two sources. First, on the basis of a case study a view of the house as a system of components and sub-components has been developed. Furthermore the locations of multiple CODP for the aforementioned components have been identified. Second, a preference measurement task applying a pairwise comparison questionnaire was conducted so as to define the level of choice expected by customers for the components.

Meredith (1998) stresses the need of case and field studies for new theory development in operations management. These are preferred methods because the explanation of quantitative as well as the set up of theories based on these findings will ultimately have to be predicated on qualitative understanding. Furthermore the application of survey research in operations management is recommended as it increases the quality of the research by reducing the gap between management theory and practice (Forza, 2002). The methods applied that help answer the two research questions are visualised in Figure 1.

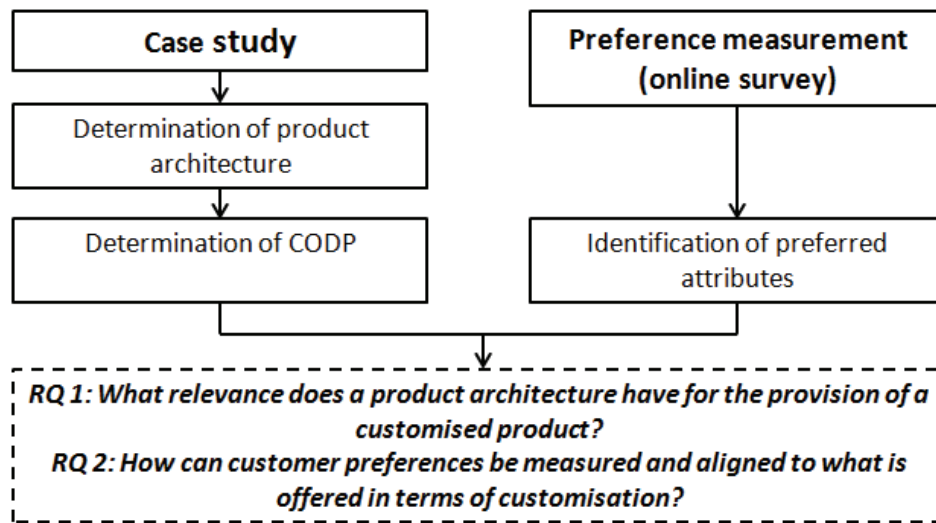


Figure 1: Visual description of method applied

**Case study**

A German prefabricated house builder was identified as case company. Over 90 years ago the operation started out as craft carpentry with a pure engineer-to-order approach. In more recent years it developed into a manufacturer of houses with a high degree of prefabrication and customisation. During a focus group discussion with the major stakeholders in the internal supply chain: sales manager, production manager, fit-out manager, purchase and technical manager the different components within the product architecture were identified. A further outcome of the focus group discussion was a product hierarchy showing categories, components and sub-components.

This has been set-up using the Affinity Diagramming technique, a simple tool that is used to structure complex data. Angell and Klassen (1999) have previously used the technique in an operations management environment.

The CODP could be positioned by scrutinising data from 16 house-building projects over a 35-year period. Comparing the standard building specification with the individual fit-out per project resulted in the determination of the items that were customised. Subsequently, an interview with the production manager as well as observation and process mapping of the material and information flows made it possible to position the CODP for each category and as a consequence for each component as well.

### **Preference measurement**

After an evaluation of various preference measurement methods a modified analytic hierarchy process (AHP) based method was identified as being suitable for this research.

The paired comparison-based preference measurement (PCPM) has been successfully applied in complex product environments (Scholz et al, 2010). Furthermore appropriate survey software was available. The AHP as such is not suitable for complex product architectures because with increasing numbers of attributes more comparisons become necessary thus potentially overburdening respondents. The PCPM, however, has four important characteristics making the tool the preferred preference measurement tool for products with a complex product architecture. First, the PCPM has a simple three layer hierarchy. Second, a static two-cyclic design is used to reduce the number of paired comparisons for data collection. Third, a bipolar equidistant scale is shown making the questionnaire appealing. And, fourth, the PCPM considers the Number-of-Levels Effect which means that the average preference weight is reduced if more attributes are included. The PCPM tackles this effect by multiplying the preference weights by the number of attributes being compared. The average preference weights then remain constant even if additional elements are included (Scholz et al, 2010).

Data was collected using an online survey. The availability of appropriate software was decisive as it is important to visualise questions effectively. Furthermore this survey method involves low costs and enables the researcher to collect a lot of data within a short period of time (Brandenburg and Thielsch, 2009).

A random sample of available e-mail addresses was selected which resulted in a sample frame of 397 potential respondents. In total 82 valid responses were received which means that a response rate of 20.65% was achieved.

## **FINDINGS**

### **Conceptualisation of product architecture based on case study results**

As mentioned above a view of the house as a system of components was developed. This was important in order to be able to scrutinise alignment of product and supply chain strategy on the sub levels. As a result of the case study a product architecture tree diagram was set up (see Figure 2).

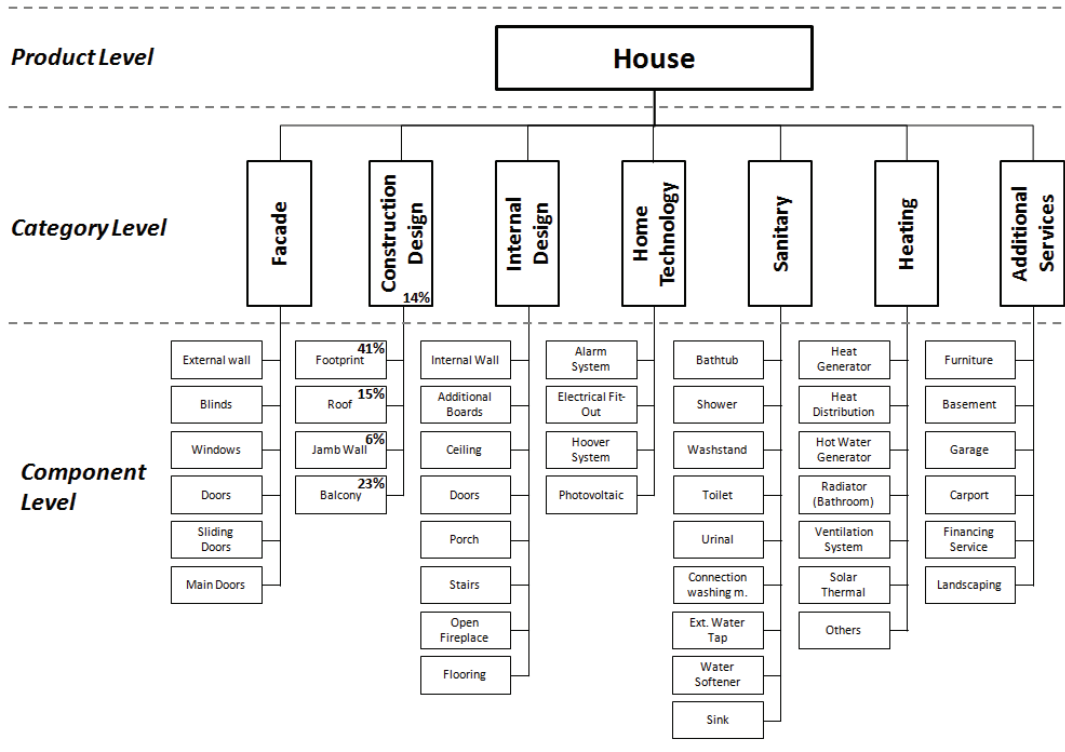


Figure 2: Product architecture of a prefabricated house

Furthermore the choice made by buyers in the above mentioned projects was identified. Due to space constraints only one category will be taken as an example in this paper. The percentage figures in the category 'Construction design' show the actual uptake of options in that category. Moreover the percentage uptake of options is shown for the 'Construction Design' as well. As can be seen although the 'Construction Design' has not been in the focus of customisation, an analysis of the components shows that from those customers who made choice within this category, the most preferred component was 'Footprint' with 41%. This includes all changes with regard to the basic layout of the house. However, it needs to be confirmed by measuring potential buyer preferences whether choice has been made by buyers only because options were available and offered during the configuration process or whether buyers actually required choice in this area. If the supply chain strategy is to offer a high degree of choice that is not actually required, this leads to wasted effort and cost.

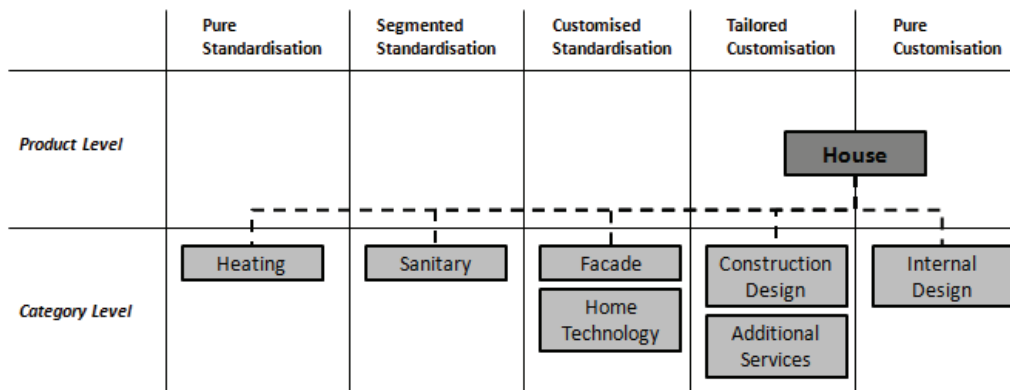


Figure 3: CODP positioning in Barlow model (2003) on category level

In Figure 3 the CODP for each category have been mapped in the standardisation-customisation model originally introduced by Lampel and Mintzberg (1996) and further refined by Barlow (2003). This shows a number of supply chain strategies. On the left hand side there is the 'Pure Standardisation' supply chain strategy which means that products made using this strategy will not be customised at all. On the right hand side there is the 'Pure Customisation' supply chain providing products make-to-order (Barlow et al, 2003). The positioning in this model has been completed using the case study data.

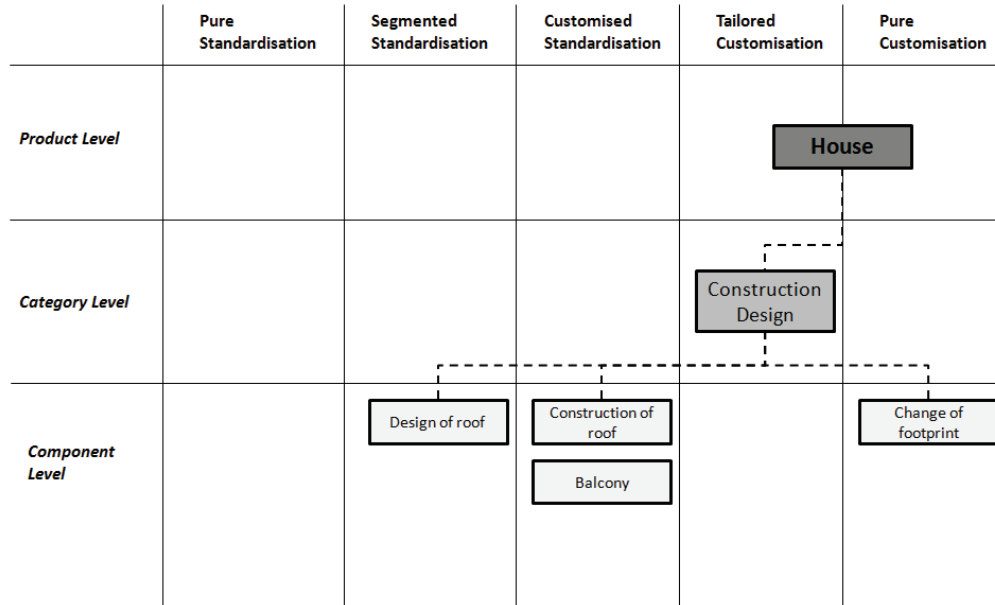


Figure 4: CODP positioning in Barlow model (2003) on component level

Furthermore in Figure 4 as an example the category 'Construction Design' has been decomposed into its components. These have then been mapped in the same model. It is important to note that although a category can be pure standardisation as per the Barlow model, the components and sub components could be categorised completely different. This highlights the importance to always decompose a product before making decisions with regard to the order fulfilment strategy.

**Aligning case study with customer preference measurement results**

Comparing the case study results showing the supply chain strategies applied for each category and component with the survey results representing respondent preferences before actually being involved in a sales process indicates that some component supply chains demonstrate good alignment while mismatches exist elsewhere. This is an important indicator for the case company as apart from the supply chain structures itself the selling process can be adapted accordingly, thus achieving customer satisfaction.

The matrix as shown in Figure 5 has been adapted from Barlow (2003) and shows two-dimensions. The x-axis differentiates between pure standardisation, segmented standardisation, customised standardisation, tailored customisation and pure customisation and the positioning of the categories has been derived from the case study. The y-axis categorises the survey results as high, medium and low choice. The appropriate percentage reflecting the particular customisation interest of respondents can be seen above the categories and components. The percentage figures presented in Figure 5 show that the respondents indicated particular customisation interest on the category level as follows: Construction Design (18.31%), Home technology (16.94%) and Heating (18.01%). This



means that for example in the Construction Design category 18.31% of potential buyers require a high degree of choice in this particular area.

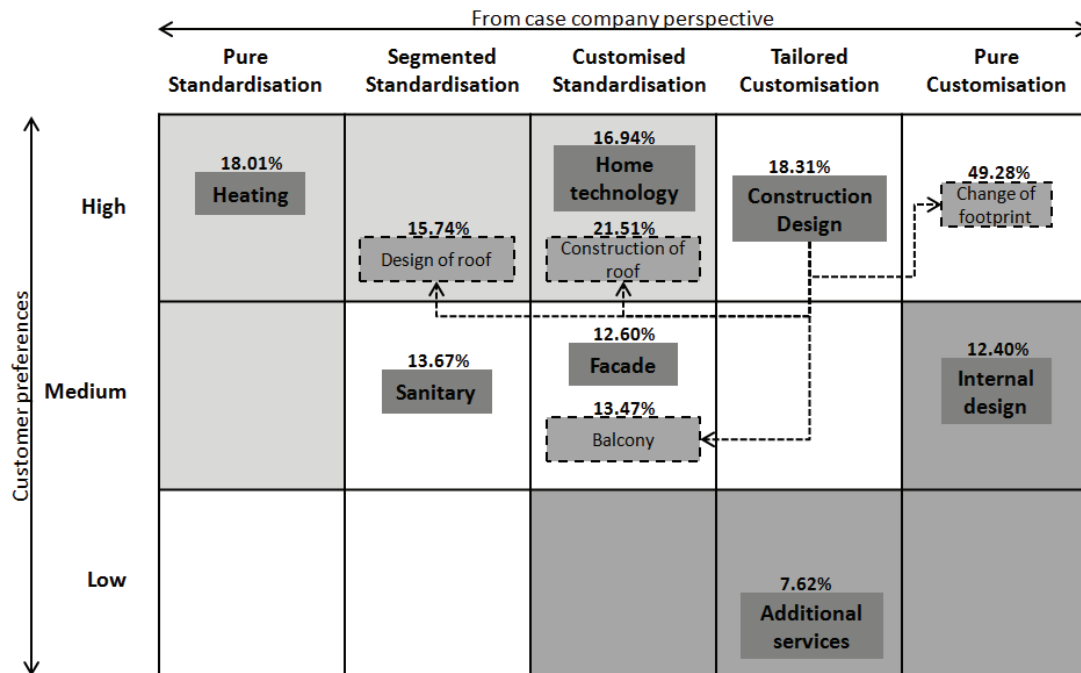


Figure 5: Supply chain alignment to customer preferences on category and component level

In categories like Internal design (12.84%) or Facades (12.60%), the need to customise is rather low. However, to conclude that within these categories customers do not wish to have a high degree of choice for certain components or sub-components is wrong. Hence it is important to consider the complete product architecture in the preference measurement exercise. Only then can the future list of options be set up according to customer preferences and needs. As an example the category 'Construction Design' has been decomposed and the components (see dotted boxes) have been mapped following the category example. This shows very clearly that although the category was categorised to be tailored customisation, the components need to be allocated to various other supply chain strategies. Furthermore, as mentioned earlier it can be seen from the preference measurement result of 'Change of footprint' (49.28%) that flexibility in designing the footprint of the house seem to be highly important for potential buyers.

As can be seen, four categories (Heating, Home technology, Additional services and Internal design) and two components (Design of roof and Construction of roof) are outside the white area which signifies the line of best fit. This means that here the choice required by potential buyers is in alignment with the supply chain strategy applied. However, only categories/components that are positioned in the dark grey shaded area are critical as customers only require low choice for these but nevertheless the company makes a customisation effort.

The categories in the light grey shaded area (Heating and Home Technology) do not require particular attention as although being very important for customers, for the company it is a Pure Standardisation category which means that no customisation effort is required. The same applies to the Home Technology category although this requires some customisation effort by the company. However, as respondents rated the importance of choice in that category as being high, it is likely that they appreciate customisation efforts by paying a price premium.

## CONCLUSION

A thorough analysis of the customisation requirements for the components and sub components is necessary as this will result in the identification of items that can potentially be removed from the option list, thereby reducing complexity and costs.

With this research a prioritisation of components and an alignment with the supply chain structure is provided which ultimately helps in designing houses that meet buyer requirements.

Past as well as current research on customisation in the construction industry is primarily concerned with an evaluation of strategic effects. There is very little scholarly interest in exploring the consequences of a customisation strategy on the supply chain structures of a construction company, particularly at the component level.

Combining the positioning of the CODP and the results of the AHP-based survey resulted in an identification of opportunities to improve strategic alignment between the supply chain structure and customer requirements. Furthermore the results enabled recommendations on how and where to remove options without diluting customer value.

There is, however, a limitation to the generalisability of this research. This is due to the research method being a single case study and the survey results being based on a random sample and only 87 responses. However, an in depth understanding of a single case study, coupled with survey responses can aid in generalisation (Meredith, 1998). Nevertheless, further research and additional cases are required to cover other populations and confirm the above findings.

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## **HUMANITARIAN LOGISTICS LESSONS FROM THE 2004 THAILAND TSUNAMI**

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### **ABSTRACT**

#### **Purpose of this paper**

The purpose of this paper is to review the events leading up to and immediately following the Tsunami disaster that occurred in December 2004 in Southeast Asia, and to highlight the lessons which were learnt from a logistical perspective.

#### **Findings**

The Tsunami highlighted many issues relating to large scale humanitarian disasters, including how best to manage logistics and supply chain activities. Consequently many organisations, especially in Thailand, began to give more attention to the issues related to large scale emergencies including prevention, planning and emergency relief operations. The lessons learned from the response to the tsunami should enable countries and organisations to better respond to such emergencies in the future.

#### **Practical implications**

While it is often the forgotten dimension of any humanitarian crisis, logistics is central to the delivery of relief aid for several reasons. First logistics is crucial to the effectiveness and speed of response for major humanitarian programmes. Without the logistics support to deliver aid to the right place at the right time and in the right conditions humanitarian aid provision will fail, or be perceived to fail, irrespective of how good the programme is. Second, logistics is one of the most expensive parts of disaster response. If the broad definition of logistics is extended to include procurement and transport, logistics forms a very significant cost element of any aid operation. Third, the fragility of emergency supply chains in extreme conditions itself emphasises the dependence of humanitarian aid distribution on reliable supply. The severing of physical links such as roads and railways is made much worse if communication mechanisms are also fractured, or if the area affected is so large that communities are unable to link their experiences to one common cause, for hours or even days. Coordination of the relief effort in these circumstances thus becomes almost impossible (Brown, 1979; Long and Wood, 1995; Kovacs and Spens, 2007).

The Asian Tsunami - December 26<sup>th</sup> 2004 - and Subsequent Events

The Asian tsunami disaster of 26<sup>th</sup> December 2004 severely affected the coastal fringe of most of the countries fronting the Indian Ocean including those in East Africa, the west Indonesian Archipelago and the Malaysian peninsula. Indonesia suffered most with more than 130,000 confirmed deaths (USGS, 2006) and almost total destruction of Banda Aceh and other coastal communities. In Thailand the tsunami was considered to be the most serious natural disaster the country has ever experienced Chanditthawong (2005).

The wave inflicted enormous damage on the six southern Thai provinces on the Andaman Sea coastline, namely: Ranong, Phang-Nga, Phuket, Krabi, Trang and Satun with Phang-Nga being the province that suffered the most damage. The tsunami was responsible for at least 5395 deaths, over 8,000 people were injured and more than 2,200 persons who were unaccounted for. The financial costs associated with the tsunami were estimated at over US\$ 500 million in Thailand alone, and this figure does not include the loss of private dwellings (Rangsit University, 2005; BBC, 2005).

Immediately following the Tsunami, aid provision across the region had to be co-ordinated on an unprecedented scale amongst a number of Governments and a wide range of NGOs, United Nations (UN) bodies, the International Committee of the Red Cross (ICRC) and the military. The scale of the disaster was so large that in the early stages of the crisis it was only possible to get aid to a few of the worst affected areas with the use of military resources. In Thailand, however, the government initially stated that they did not wish to receive help from external sources, particularly in the immediate aftermath of the tsunami.

### **Tsunami warning and evacuation**

Following the December 2004 Tsunami, there was a clear need to revisit disaster planning with regard to this type of event. A major review of preparation plans, evacuation procedures and future planning contingency measures was therefore conducted. A Master Plan for Tsunami Evacuation (DPM, 2005) was developed, falling within the remit of two Government Acts (the Civil Defense Act and the Building Control Act) and two Government plans (the Civil Defense Plan and the National Preparedness Plan). The areas which were identified as being vulnerable to the Tsunami hazard consist of mainland Thailand fronting the Andaman Sea, and all islands and island groups in the six southern provinces of Ranong, Phang-Na, Phuket, Krabi, Trang and Satun. The vulnerable areas are split into sub-districts and villages.

The Master Plan tasks, the Regional Civil Defence Directing Center (RCDDC) to direct, control, administer and provide recommendations about Tsunami prevention and mitigation. The emphasis is primarily on evacuation, communications and victim support, and reference to the distribution of aid materials to disaster victims, mainly focuses on supplies, temporary shelter and health / welfare materials. Thus within its remit, transport and logistics support are implicit rather than explicit. Three main phases are highlighted: Pre-disaster; During disaster and Post-disaster, consistent with other disaster response approaches (e.g. Carter, 1999). The pre-disaster phase highlighted all communities at risk to heighten individuals' awareness of the procedures needed to be adopted in the event of a Tsunami strike. Specifically the preparations involve identifying safe areas for evacuation, main and alternative evacuation routes, signage and maps showing these routes, emergency support units and the provision of vehicles, as well as tools and obstruction clearance equipment. Several models have demonstrated that 15 metres above sea level is generally safe and 20 metres above is safe in virtually every tsunami case. The dissemination of Tsunami warnings is in the first instance from two types of warning towers activated from a central location near Bangkok. The first type is manned at the time of an emergency, and is maintained and monitored by the Royal Thai Navy. The second type

takes the form of automatic unmanned warning towers which have been installed along the beaches in the six provinces bordering the Andaman Sea. Both types emit a warning either as a siren or amplified verbal alarm. Immediately backing up these initial warnings is an Amateur Radio Network which disseminates warning information from 76 Control Stations (one in each province) via an Echolink System and normal frequencies in the amateur radio network to provincial users of these networks.

The emphasis of the Thai Government's approach is on clarity of responsibility and communications networks. Regarding the evacuation of people, there is a priority order and all villages must have arrangements for evacuation to safe areas. Areas designated as 'safe' are either outside the zone affected by the December 2004 Tsunami or on land higher than 15 metres above sea-level. These safe areas, area as far as possible, identified, advertised and signed. Similarly, primary and alternative evacuation routes are identified so that all communities have at least two routes to safety. Learning from the experience of the December 2004 event the Thai government has recognised the importance of an effective telecommunications network which can support both the evacuation procedures and any post-Tsunami provision of aid and effective logistics operations (DPM, 2005).

Once a Tsunami alert has been given, assuming it is then cancelled, the resident population will be able, to return to their property, the return being managed by nominated community leaders in cooperation with evacuation officials. Where appropriate, the RCDDC coordinates with military units, governments agencies, private companies (such a transport companies) and other organisations according to need. Overseeing the three phases is the National Disaster Warning Centre which is operational 24 hours a day regardless of whether or not there is an emergency.

### **Logistics, transport and information gathering**

Subsequent to the tsunami, a review of how humanitarian response is carried out following major disasters (United Nations, 2005) was carried out and a new approach was developed known as the cluster system. Within this system WFP are now the lead agency for the logistics cluster, the first logistics cluster being formed following the Yogyakarta Earthquake in May 2006. The most recent example of the effective use of the cluster system was seen following the Haiti earthquake of January 2010 (Whiting, 2010; Heraty, 2010a; 2010b).

Further, the degree of disruption, coupled with the surprise element and the sheer scale of the tsunami, generated a very high level of information inaccuracy. Getting an accurate picture of the Tsunami impact and needs on the ground was a key priority in the hours after the tsunami waves struck. This encouraged responsible agencies to engage in various triangulation techniques (a widely used information and data verification method) in order to iron out as much uncertainty and information conflict as possible. Subsequently, for this purpose, Banomyong *et al* (2009) proposed using two triangulation techniques known as data triangulation and investigator triangulation (Denzin, 1989; Denzin and Lincoln, 1998) to reflect as best as possible the "real" situation on the ground.

Data triangulation largely employs the use of published and unpublished papers, media coverage and on-the-ground reporting. Observations are backed up by data collected from several different secondary data sources such as websites, published and unpublished research work, contemporary media coverage and tsunami inquiry reports. The purpose of the data triangulation technique is to provide a broad coverage of the literature that relates to the incident and to reconcile it with observations on the ground.

Investigator triangulation, meanwhile, makes use of different respondents involved in the same event at the same location. During and immediately following the tsunami strike, there were thousands of innocent victims who became active participants in the information collection process and who played a key role in trying to alleviate the disaster. This technique was utilised to gain the best possible understanding of the situation from multiple perspectives, i.e. how relief operations were conducted and how they could be improved. Having accurate data on the nature of the disaster, its extent, the number of affected persons, and the volume and type of goods needed are clearly a prerequisite for successful relief operations. Lessons to be learned can be derived from these two methodological approaches.

### **Reflections and Lessons to be Learned**

In spite of the findings of a large number of 'After Action Reports' since the Asian Tsunami, all too often the focus has been on high level 'policy' rather than on addressing the underlying problem. Humanitarian Aid, as has been shown, is largely about logistics, which in essence is 'End-to-End Humanitarian Supply Chain Management' – everything from procurement, through purchasing, to delivery to the beneficiaries. Without robust logistic solutions the best "programmes" in the world will consistently fail to deliver aid quickly to the right people, at the right time, in the right condition and for the right price. In an emergency, logistics can account for as much as 70% to 80% of the overall cost of aid depending on the location of the crisis and circumstances; this is up to twice as high as figures often quoted for commercial supply chains in stable conditions. It follows that if organisations are to improve their ability to respond quickly, the logistics processes - and the professional training of those responsible for delivering them - must be the best that can be provided.

In 2005, following the Asian tsunami, under pressure from donor countries to improve the effectiveness of emergency response, the then UN Emergency Relief Coordinator (ERC) commissioned an independent Humanitarian Response Review (HRR) of the global humanitarian system (United Nations, 2005). The HRR was tasked with identifying those factors that have frequently hindered the speed and effectiveness of humanitarian response in the past, and to propose appropriate steps towards improving both the *timeliness* and *impact* of future humanitarian interventions. Four independent consultants undertook the review and, through adoption of customised questionnaires, face-to-face interviews, seminar discussions and reviews of background documents, the consultants assessed the humanitarian capacities of the major international organisations.

The draft HRR report concluded that:

*"It is imperative that agencies learn to look beyond individual capacities in order to achieve greater and more effective response capacity."*

This is apparent, for example, in the development of stockpile capacity where the responses to the consultation show a picture of very uneven capacity. The draft HRR was believed by some to be flawed, since it focused on international response only and overlooked local *and* national responses which in the immediate aftermath of the tsunami (and also seen more recently in the response to emergencies such as the Wenchuan earthquake (Beresford *et al*, 2009)) are extremely important. A number of observations and recommendations were made on covering the need for change and improvement. As a result of this debate, however, it was resolved that the priority for improving the humanitarian system should be the development of what is now known as the cluster system. In this system lead responsibility is taken by a particular organisation, which in the case of the 'logistics cluster' is the World Food Programme.

The HRR issued its Final Report in August 2005. The review encompassed several critical areas, including:

- an assessment of existing humanitarian response and identified gaps
- recommendations for mapping the response capacities of national, regional and international parties
- strengthening response capacities, particularly human resources
- application of benchmarks to measure and control performance
- improvement of coordination, and
- the disparity between desired and current capabilities in the provision of emergency water and sanitation, shelter and camp management, and protection.

The HRR recommended assigning responsibilities by sector to lead organisations and the development of cluster models.

The IASC Principals agreed that the cluster approach should be applied, albeit with some flexibility, at the country level. The cluster concept is seen by the UN as a **genuine** means of improving the way that the humanitarian response system works, and of ensuring more effective accountability. The intention is that cluster leads will provide a means of supporting the Resident and Humanitarian Coordinators in ensuring an integrated and coordinated response.

It is important to appreciate that the Cluster Concept was developed by the IASC and it is thus seen by some as a creature of the UN and, until the last quarter of 2005, NGO involvement was limited (ICVA, 2005). It is also important to appreciate that non-governmental humanitarian action is, by its very nature, voluntary and NGOs do not lend themselves to top-down coordination by the UN system, not least because their structures are often highly decentralized. It is precisely for these reasons that the HRR failed to assess the NGO capacity satisfactorily. The sheer number of NGOs operating in Indonesia



immediately post-tsunami was a case in point. Meaningful capacity and capability estimation was virtually impossible.

The designated lead organisation for Logistics was the WFP. Between August and December 2005, WFP established a Logistics Cluster Working Group <sup>1</sup> (LCWG) and engaged in discussions with other UN agencies and NGO partners. The Logistics Cluster WG aims to improve surge capacity, speed and effectiveness of humanitarian response, thus ensuring better logistics preparedness and response, and facilitating improved inter-agency interoperability through the pooling of resources.

There can be no doubt that, in principle, surge capacity management was at the heart of the logistics response in the aftermath of the Asian Tsunami, so in the event of a similar emergency in the future, response should better fit needs. On 6 March 2006, the LCWG presented the logistics gaps, and activities to fill these gaps. The Logistics Cluster operates under the following precepts:

- **Logistics:** The Fritz Institute defined *humanitarian* logistics 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” (Thomas and Kopczak, 2005).
- **Logistics Cluster** <sup>2</sup>: Group of humanitarian organizations and other stakeholders (Participants) committed to commonly address logistics needs during humanitarian crises (global and field)
- **Logistics Cluster Participants:** Individual organizations with recognized institutional logistics capacity that are involved in the logistics cluster approach and can provide dedicated staff (global and field)
- **Logistics Cluster Lead:** Organisations appointed (WFP) by the Inter-Agency Standing Committee (IASC) to take the lead in:
  - the implementation of the logistics cluster approach;
  - be accountable to the Logistics Cluster Participants and the Emergency Response Coordinator (ERC) or Humanitarian Coordinator (HC); and

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<sup>1</sup> The Logistics Cluster Working Group is led by WFP and participants at the global level include IOM, WHO, UNHCR, UNICEF, OCHA, the United Nations Joint Logistic Centre (UNJLC), UNFPA, ICRC, IFRC World Vision International (WVI), Care, Catholic Relief Services (CRS), Save the Children (SC), and FAO.

<sup>2</sup> An introduction to the Cluster Leadership Approach is available in the ‘Guidance Note on using the Cluster Approach to strengthen Humanitarian Response, 24<sup>th</sup> November, 2006’ which can be found at <http://www.humanitarianreform.org/humanitarianreform/Portals/1/Resources%20&%20tools/IASCGUIDANCENOTECLUSTERAPPROACH.pdf>.

- be the provider of last resort (global and field).

The Logistics Cluster participants agreed on following criteria:

- Accountability of Cluster Lead Agency: Cluster Leads are accountable to the ERC/HC for ensuring adequate preparedness and effective responses in the sectors or areas of activity.
- Provider of Last Resort: commitment of cluster leads to do the utmost to ensure an adequate and appropriate response.
- Option 1: a critical gap is identified and the lead agency requests a Logistics Cluster Participant to fill the gap.
- Option 2: a critical gap is identified and no other agency is capable or willing to fill this gap. The lead agency will use its capacity to address the gap on the condition that funding becomes available.

### **Postscript 2012**

In April 2012, a full-scale tsunami alarm was raised following an 8.6 Richter Scale earthquake off Indonesia. Although no subsequent tsunami occurred the local response mechanisms were invoked in the 8 hour period immediately following the alarm. In the Krabi area more than 2000 people (tourists and locals) were successfully evacuated to higher ground. The wider response of the logistics cluster was thus not required on this occasion

### **CONCLUSIONS**

In the case of the Asian Tsunami of 2004, the vast majority of people with logistics responsibilities did not have training in logistics. Large multinational corporations acknowledge that one of the biggest challenges in logistics is the identification, recruitment, training and retention of quality staff. The trend towards the “professionalisation” of logistics has been slow to take hold in the humanitarian world, as field experience is considered much more valuable than formal training in logistics.

One of the starkest messages the tsunami provided was the fact that the effectiveness of humanitarian aid response hinges on logistics efficiency. It is imperative that, for humanitarian logistics to adequately serve the purpose of successful delivery of aid, the humanitarian aid organisations at large must recognise the role that logistics plays in the delivery of programmes large and small, and the need for humanitarian logistics to be adequately resourced in terms of trained and capable staff, adequate information management systems, and logistics infrastructure.

In many areas the lessons identified as a result of the Asian Tsunami 2004 remain just that – lessons identified – they cannot qualify as lessons learned. Only in specific areas such as disaster planning and preparedness in Indonesia and Thailand have lessons been learned, some of which were seen in the immediate response to the April 2012 earthquake. The key factor is that, with the greater incidence of concurrent sudden-onset natural disasters affecting the lives and livelihoods of more and more people focus needs to be on building national and regional capacity and developing robust national and regional disaster and response plans – the success of this approach in Indonesia and Thailand is clear. The need for humanitarian logistics to embrace commerce, academia and the military and to share experience and assets is also obvious. More than ever, logistics needs to show the way by advocating a dynamic alignment of concepts and ideas which will deliver consistently – the

right products, to the right place at the right time and in the right condition for a price that is transparent and measurable.

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## Section 10 – Services and the Supply Chain

### THE ROLE OF INTER-ORGANIZATIONAL SYSTEMS QUALITY FOR SUPPLY CHAIN MANAGEMENT – A SYSTEMATIC LITERATURE REVIEW

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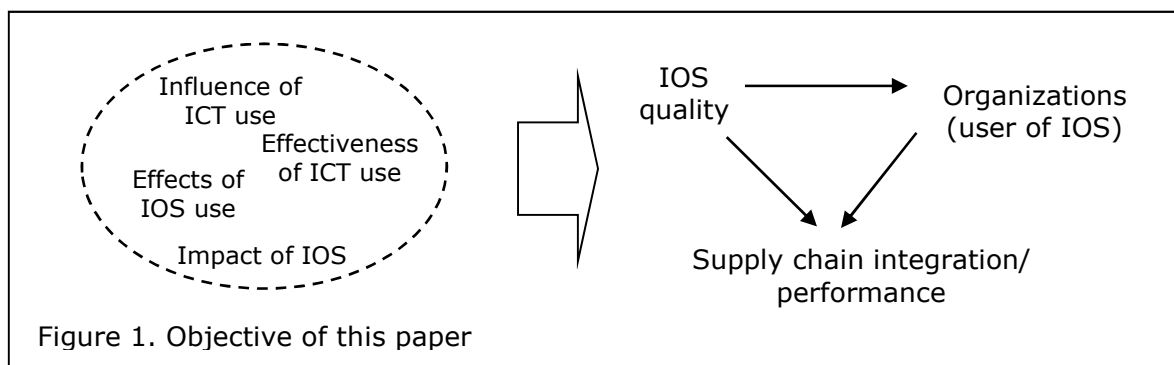
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#### 1. INTRODUCTION

An Inter-Organizational Systems (IOS) refers to an information system spanning more than a single organization (Bakos, 1991). With recent trends of IOS use for supply chain management, the integration of business processes through IOS has been investigated in several research areas, such as extent (what to integrate), scope (who to integrate) and effectiveness of integration (what is achieved) etc. However, despite of various interests on IOS use, little research to date has examined how integration and effectiveness is achieved through IOS. For this reason, this paper conducts a systematic literature review to identify the role IOS in supply chain integration and their effectiveness.

#### 2. RESEARCH OBJECTIVE

The issue of 'how to integrate organizations' through IOS faces several problems which need to be addressed. Firstly, there is little research that has tried to evaluate supply chain IOS. In order to complete an integrated network, firms need to be interconnected via IOS. This means that a valuable IOS should maintain high quality of information services for chain members to be well-integrated. Therefore, IOS quality verification is important in evaluating the excellence for supply chain IOS. Secondly, there is an ambiguity in the concept of IOS in terms of its effectiveness. A number of research paper have adopted the ideas of 'influence of IOS use', 'effectiveness of IOS use' and 'performance of IS'. However they do not have clear conceptual boundaries between system, organization (system user) and system effectiveness. Consequently, the concept of system technology and the effectiveness of systems are often treated as the same area, even though the effectiveness is the result of technology utilization. Finally, current integration research has given weight to IOS effect analysis rather than effect materialization process. As a result, the main research outcomes focus on final benefits of IOS utilization, not the IOS itself or the role of IOS in the integration process. In order to explore these issues addressed above, this paper sets up three research questions: 1) what are the quality factors of supply chain IOS?; 2) How does IOS quality affects the organizations to achieve supply chain integration and performance ?; 3) what are the relationships between IOS quality, organizations and performance? By answering these questions, this paper tries to achieve a clear delineation between the IOS quality, organizations and the effectiveness of IOS in supply chains.



### **3. RESEARCH APPROACH AND METHOD**

This review consists of two main sections. The first part is IOS quality construct identification and the second part is an effectiveness analysis of IOS quality.

#### **3.1 IOS quality identification**

In the first part, IOS quality construct was identified by examining selected articles. In order to clarify the concept of IOS quality, this paper adopts the concept of IS (Information Systems) quality which refers to usefulness of information systems in an organization, such as excellence, value, fitness for use, meeting user requirements (Swanson, 1997). The IS quality concept needs to be distinguished from software quality. Software quality represents engineering and programme centred view on IS but IS quality is an organizational concept which is highly associated with managerial process improvement through IS (Kuo 2009). One of the most qualified approaches to IS quality is the IS Success Model (Cullen and Taylor, 2009) proposed by DeLone and McLean (1992). Based on 180 reviews, it identified three interdependent components which construct IS quality and affect organizations to materialize the effectiveness of IOS (Gorla et al., 2010). The first element is systems quality which is the measures for information processing itself. Secondly, Information quality refers to the measures for information output of the system. Lastly, Service quality represents the measures for the overall support delivered by the system provider (DeLone and McLean, 1992, DeLone and McLean, 2003)).

#### **3.2 Impact analysis of IOS quality on supply chain management**

The second part focuses on the effects of IOS quality on organizations and supply chain effectiveness. The effects were categorized in three streams, which are direct effects of IOS quality on performance (stream 1), organizational effects of IOS quality (stream 2) and supply chain performance through organizational effects (stream 3).

In order to demonstrate the effects of IOS quality on organizations, the concept of interoperability is employed. In supply chain network, firms are actual stakeholders and principal agents who cooperate with each other and coordinate shared processes. However, these integration abilities are created and provided by using IOS. Mouzakitis et al. (2009) conceptualized this consequence as an idea of interoperability, which represents the ability of organizations to work together with trade partners. If interoperability concept can be identified from the selected articles, usefulness of IOS on organizations also can be crystallized. Moreover, by adopting this concept, the position of firms in integration process is clearly distinguished from the ambiguity around the concept of 'effectiveness IOS use'. To take account of the various technical issues and organizational content of interoperability, identified interoperability was categorized in different levels of integration depending on the relationship patterns between trade partners (Premkumar, 2000). The first level is Information sharing level which is the formation of a virtual relationship through IOS to increase the scope of process visibility (Saeed et al., 2011). The second level is Process level integration which represents a network for business process coordination (Premkumar, 2000) Thirdly, the Knowledge level integration focuses on knowledge expansion for organizational capacity based on value creation (Simatupang et al., 2002). Finally, the Trust and commitment level refers to network formation for the same business goals and purposes based on mutual trust and commitment (Bagchi and Skjoett-Larsen, 2005).

In terms of supply chain performance, general performance measurement factors based on literature review research by van der Vaart and van Donk (2008) is applied. The selected performance constructs are overall performance measures (market share, financial turnover), operational cost, customer service, logistics capacity, and asset management.

### 3.3 Article selection

For an holistic approach to the research object, a systematic literature review with key words was deployed. In order to collect relevant articles to the research questions, the review was conducted in the order of article selection, quality enhancement and inclusion/exclusion of articles. First of all, the literature search was conducted using an academic search engine (ABI/INFORM Global) with a combination of keywords. The combination used was ("information system\*" AND ("supply chain" OR "logistics" OR "transport\*")). For quality enhancement, articles only from the ABS (the Association of Business Schools) journal list were included (Harvey et al., 2007). In inclusion/exclusion process, only articles discuss inter-organizational relationship based information systems were included. In order to focus on the IOS and its quality, articles only discussing any dimension of IOS which can be interpreted into three types of IS quality elements from IS Success Model were included. Finally, articles examining the relationship between IOS quality and its effects on supply chain management were also included.

### 4. FINDINGS

38 articles from 17 academic journals were finally selected <sup>1</sup>. 31 articles are empirical

Research approach	Article research streams						Total
	Stream 1: IOS quality → Chain performance		Stream 2: IOS quality → Interoperability		Stream 3: IOS quality → Interoperability Performance		
Empirical Research	Survey	6	Survey	6	Survey	6	18
	Case study	-	Case study	4	Case study	8	12
	Interviews	-	Interviews	-	Interviews	1	1

research which tested the impact of IOS quality with survey, case studies and interviews while 7 articles were conceptual papers which suggested solutions to improve IOS quality for efficient supply chain integration and performance. IOS types were diverse, such as e-market place, e-procurement systems, integrated logistics systems and RFID applications etc. Table 1 summarizes selected articles depending on research streams and methods.

Table 1. Research streams and methods of selected empirical research articles

#### 4.1 IOS quality

Several IOS quality elements were identified from selected articles. Accuracy, visibility, standardization and currency were extracted as main components of information quality. Accurate information on the product and process are critical for communication with partners and customers (Byrd et al., 2008). Moreover, the currency which indicates the real-time information for relevant situation plays a key role as the logistics information needs to be delivered in timely and accurate manner (Malhotra et al., 2005). A standardized information format is also essential as the information need to be easily interpreted and presented for system users (Chow, 2004).

Information Quality	Description
Accuracy	Accurate information for process and products
Visibility	Quality presentation for shared information
Shareability	Shareable information with

<sup>1</sup> Full reference list is available from HanJH@cardiff.ac.uk

	external partners
Currency	Up to date and relative information
Standardized information	Standardized format of information

Table 2. Identified Information quality

For system quality, reliability, availability and speed which were introduced in the original IS success Model are also captured. Moreover, newly identified factors which mirror the dynamic dimensions of IOS utilization in supply chain management are also identified. For example, networking capability which represents system connectivity and compatibility was discussed as primary quality factors. By connecting a range of applications and systems across firms, a wide scope of information exchange availability was assessed as a critical factor (Keah Choon et al., 2010). Compatibility was pointed out as the applications and systems need to be easily interlinked in virtual networks (Talluri, 2000). Smartness which covers process automation and advanced information processing is also crucial. Because the advanced processing ability of IOS improves operational efficiency by enhancing the controllability of transactions between partners (Danese, 2006). Ease of use and customized system were also discussed. Systems should be easily operable and fit for the business purpose to prevent firms from any opportunity cost caused by inappropriate user interface for business purposes (Bienstock and Royne, 2010). Flexibility is the ability of information processing in various working conditions. In order to cope with any unexpected user requirement and circumstances, IOS need to be prepared for a large amount of information processing in diverse services areas (Sanna et al., 2007). Table 3 summarizes the identified system quality elements.

System Quality	Description
Smartness	Advanced and automated information process execution
Customization	System fitness for business purpose and strategy
Networking Capabilities	Capability for networking across applications and platforms
Reliability	Error free processing, higher level of security
Speed	High speed of information processing, real-time distribution
Ease of use	Ease of use system
Flexibility	Data storage service, strong capacity for information distribution
Availability	Accessibility on demand and in adequate forms by various users

Table 3. Identified System quality

Since IOS is for everyday operations (Harry et al., 2007), the quality of service providers for system maintenance and support were identified as critical factor. Moreover, training sessions and continuous service improvement help users and firms utilize the IOS in more effective ways (Chow, 2004).

Service quality	Description
Quality of service provider	Higher skills& knowledge, regular training, service evolution maintenance,
Cost	Lower systems adoption and support cost

Table 4. Identified Service quality



#### 4.2 Research stream 1: Direct effect

8 articles demonstrated the direct effect of IOS quality factors to supply chain performance. Especially, David et al. (2005) and Evangelista et al. (2012) proved that there is positive relationship between system networking capability and supply chain performance, such as logistics capability and asset management.

#### 4.3 Research stream 2: Interoperability for supply chain integration

In this part, selected articles were classified under the four levels of integration proposed earlier. Simultaneously, the interoperability was also examined to identify the effects of IOS quality on organizations. Firstly, interoperability enhanced by IOS quality in the information sharing level is identified in various forms of organizational ability. The ability to establish virtual networks (Harry et al., 2007), ability of track/tracing business process (Zelbst et al., 2010) and ability for external accessibility (Harry et al., 2007) appear in this level since information sharing between firms is enabled when the information is sent and received via IOS. In the process level of integration, interoperability focuses on the coordination of mutual transactions by trade partners. For example, the ability for process coordination and process acceleration (McMichael et al., 2000), collaborate for shared process (Saeed et al., 2011) and negotiation with trade partners (Puschmann and Alt, 2005) were addressed. By achieving processes coordination ability, trade partners are able to have standard business process for more

Table 5. Interoperability in different integration level

Integration	Interoperability	Description
Information sharing level	Ability of external accessibility	links for external trade partner & customer access
	Ability of e-network formation	Virtualized network
	Ability of track & tracing	Real time track & tracing
Process level	Ability to process coordination	coordination for operational efficiency
	Ability to collaborative transactions	cooperative operations for complex transactions
	Ability to negotiate	Functionality for negotiation
Knowledge level	Ability for Knowledge & value creation	knowledge creation for logistics process/ efficient business report
	Ability for knowledge & value management	value & performance analysis, supply chain reconfigure-ability
Trust & commitment level	Ability to build relationship for business forecasting	relationship building for business forecasting and planning
	Ability to build relationship for the same purpose	relationship formation for the same purpose based on trust & cooperation

efficient transaction processing (Jayaram et al., 2000). At the knowledge level, firms focus on the organizational capacity in terms of knowledge creation and expansion. For example, supply chain reconfiguration ability (Wei and Wang, 2010), ability to conduct precise performance analysis and produce efficient business reports (Genevieve, 1998) were identified as critical elements. Finally, the trust and Commitment integration level refers to the level of network formation for the same business purposes. The interoperability at this level mainly focuses on organizational capability for formation of longer-term collaborative relationships. (Keah Choon et al., 2010).

#### 4.4 Research stream 3: Supply chain performance through interoperability

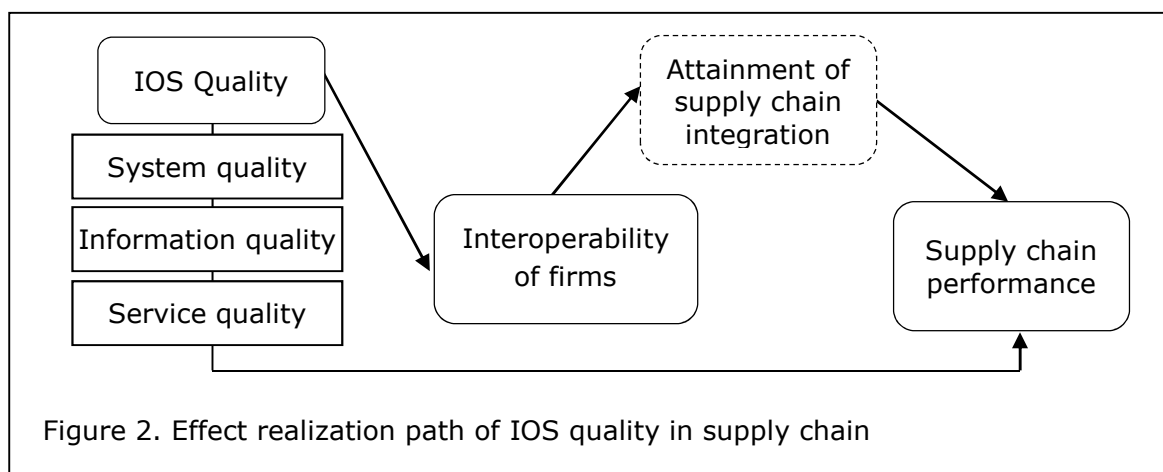
Effectiveness materialization through firm's interoperability is also captured in various forms of performance measurements. Table 5 lists an overview of performance measured by 15 selected articles. Customer satisfaction through higher responsiveness, asset management with inventory management and improved speed through real time information sharing were mainly discussed as critical performance measurement. Especially, competitiveness (Keah Choon et al., 2010, McMichael et al., 2000) emerged as an additional performance measurement factor compare to the direct effect of IOS quality on performance.

Performance measurement	Description
Logistics capacity	- Improved responsiveness among logistics operations - Logistics leveraging effect - Transparent operations
Competitiveness	- Firm resource optimization with flexibility - Increased supplier integration
Asset Management	- Improved ROA - Reduced inventory holding cost - Improved inventory management
financial performance	- Reduced distribution cost - Reduced document cost - operation cost reduction & improved turn over
Improved Speed	- Improved transaction speed/lead time - time performance

Table 6. Performance realization through interoperability

#### 5. CONCLUSION

This review examined an IOS quality construct and the role of IOS quality in supply chain integration. Firstly, diverse quality elements were identified and classified into information quality, system quality and service quality by adopting IS quality concepts from the IS success model. Secondly, the effect realization path of IOS quality on supply chain can management was divided into two categories. The first path is the direct effect of IOS quality components on supply chain performance. The second effect realization path is the performance realization through firms' interoperability. Moreover, organizations' interoperability was identified in different levels of integration in order to demonstrate the effects of IOS quality on organizations. Figure 2 presents relationships among those components.



#### 6. DISCUSSION AND FURTHER RESEARCH

This paper highlights three research issues that need to be discussed further. Firstly, the discussed content is closely related to the methods of 'how to integrate best through IOS' not only 'how to integrate through IOS', because they discussed the quality of IOS which

has the possibility to be improved. The possibility of quality improvement is discussed in 7 conceptual papers from the selected articles, such as participated systems assessment by users (Remenyi and Sherwood-Smith, 1999), an intelligence of IOS for optimized process scheduling (Kelleher et al., 2003) and higher information distribution capacity (Nessen, 2002). Secondly, the importance of a firm's interoperability needs to be inspected further, as firms are main actors of integration activities. In addition, in order to clarify the ambiguity of 'effectiveness of IOS use' idea, the position of firms in the integration process needs to be closely investigated by identifying the interoperability. Finally, appropriate theories should support the relationship between IOS and organizations to increase the validity of this research, because it is a non-human and human relationship for functionality creation which is not familiar in conventional supply chain research.

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## THE DEVELOPMENT OF THE SERVICE SUPPLY CHAIN FOR A MANUFACTURING SME

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### ABSTRACT:

Servitisation has been a widely discussed topic for researchers and practitioners in recent decades. However, the development of the industrial service business is a very challenging task for small and medium-sized manufacturers. We have supported Finnish industrial manufacturers to move from goods-dominant logic (G-D logic) towards service-dominant logic (S-D logic) with a practical step-by-step method. This paper discusses service business development in the context of small and medium-sized manufacturing companies' service supply chain realisation.

Keywords: Service-Dominant logic, service supply chain, SME, development, manufacturing industry

### Introduction

Firms in various industries are finding that they can no longer succeed just by offering excellent products, traditional after-sales service, and logistics (Kowalkowski et al. 2013). To differentiate themselves from their competitors, manufacturing firms have begun to extend their range of service offerings and enhance their service orientation (ibid). There are many terms in use to describe the change from traditional manufacturing for providing services. Manufacturing firms increasing their focus on service also has been referred to as the emergence of "product-service systems" (e.g. Tukker & Tischner, 2006) and "servitisation" (e. g. Vandermerwe & Rada, 1988). Kowalkowski et al. (2013) have used "service infusion in manufacturing firms" to capture the empirical phenomenon, the common denominator of which is the increased importance of service in the offering and organisation of manufacturing firms. Vargo and Lusch (2004) have argued the transition from a theoretical point of view, in terms of the movement from a goods-dominant (G-D logic) logic towards a service-dominant logic (S-D logic).

Of the studies that seek to understand this service business phenomenon, most focus on large multinational firms and only a few studies are known of service infusion in small and medium-sized enterprises (SMEs) (Kowalkowski et al. 2013). Gebauer et al. (2010a) have argued that existing findings cannot be transferred to the context of SMEs, as research neglects how a firm's size may affect service business development. Kaski et al. (2011) have done a study focusing on SMEs which are currently aiming to transform to a service business or are developing their service concepts. Their selected case companies represented ICT (information and communication technology) and KIBS (knowledge intensive business services) industries, not purely manufacturing (Kaski et al. 2011). Maybe the largest available study about service development in manufacturing industries has been done by Gebauer et al. (2010a), with longitudinal action research and interviews with SMEs from Italy, Sweden and Switzerland. Gebauer et al (2010a) compare their findings to multinational enterprises (MNEs) and the main conclusion is that the service strategy formation and implementation in SMEs depend on their value chain position and the business environment. Strategic positioning is the starting point for service business development. Companies should identify which kind of role they should take in the value chain with the new service offerings.

Considering the previous scientific discussion and the practitioners' increasing need for service supply chain development, there is a need for further information about the subject. Thus, the aim of this paper is to increase the understanding of service business development by further developing previous conceptual frameworks from the scientific literature. In doing this, we use two case SMEs from the Finnish manufacturing industry.

### **Methodology and research approach**

The purpose of the study is to develop a step-by-step method for the manufacturing SMEs transforming towards a service business. The qualitative case study research approach was chosen to gain both theoretical and empirical insight into the little researched topic (Yin, 1994). The case study form was seen to work in the research for discovering causalities of the phenomenon (Jensen and Rodgers, 2001; Yin, 1994).

The research is based on constructive case study research (Yin, 1994), where we have developed a new construct (step-by-step method) for service business development. This study is based on the theoretical data received from the literature review and on the empirical case data. More specifically, we have used the literature findings, especially from the service-dominant logic approach, when trying to find service innovations within case studies. Due to the fact that the main data source of the study was guiding and conducting the development and analysis of the supply chain, the study can be said to have features of action research strategy (e.g. Crisholm and Elden, 1993). The experience and insights of the business informants was considered essential in order to make in-depth sense of the phenomena (Eisenhardt, 1989). Furthermore, the use of key informants in an expert group analysis allowed great depth and richer description (Voss et al. 2002).

By using workshops we developed the service models for case companies. Companies have implemented new service models and we have analysed how successful the development has been. The value of this paper lies in the description of the method, which can help practitioners to develop service offerings.

### **Existing servitisation methods**

Generic service business development methods are available in the literature, but step-by-step methods are rare (Kaski et al. 2011). There are many different approaches to service business development, like New Service Development, Service Design and Service Engineering. New Service Development refers to the product development process, which supports individual service product development from the idea to market launch (e.g. Menor et al. 2002).

Service Design focuses on the designing of individual tools, methods and content that are used for the development of the service offering (Menor et al. 2002). Service Engineering is an approach for capturing services as an R&D object made within the project under the general heading of "service engineering", and an attempt is made to systematise the development of services (Bullinger et al. 2003). Bullinger et al (2003) have listed the following topics as relevant to service development management:

- organisational design aspects in service development
- human resource management in service development
- information technology support in service development

Organisational design means that a company might have a separate organisational unit to develop services or another alternative is for existing organisational units to assume service development tasks (ibid). Human resource management plays a crucial role in connection with development tasks, because development outcomes depend to a large extent on the competence and interaction of the persons involved in the development process (ibid). Bullinger et al (2003) argues that that new procedures and methods

become established more easily if they are able to be adequately supported by modern information and communication technology. These three service engineering topics are especially critical for SMEs, because they usually have limited organisational structures, human resources and IT systems. Bullinger et al. (2003) have criticised the existing service development model as follows:

- Insufficient level of detail: the models generally describe the higher-level process steps, but not the concrete activities nor the methods to be deployed.
- Lack of configurability: all the models simply define a rigid development process, without allowing for any form of adaptation to different service types.
- Lack of practical corroboration: all known reference models in the area of service research are the result of theoretical observations and have been only inadequately tried out and tested in practice.
- Lack of ICT support: none of the models offer any points of contact that might allow the development process to be supported with modern information and communication technology (ICT).

Bullinger et al. (2003) have partly covered weak areas in their service engineering approach. We have also paid attention to these weak areas, and according to our research these weak areas are exactly the most challenging for SMEs during the development.

Moving towards a service business is a huge step for a company and requires all business functions to be involved in the development, despite SMEs having limited organisational structures. Several models describing the process of new service development have been developed and usually those include the definition of clear milestones, gates and stages (Kaski et al. 2011). These models typically suggest that the development process is a sequence of phases during which the initial ideas for a new service are refined into a deliverable service (ibid).

It is important for academia to understand the service business phenomena and the success of the service business in manufacturing firms. From the practitioners' point of view, it is more interesting to understand how to develop service offerings. Our step-by-step model has been influenced by existing development models but it addresses the SME limitations.

### **Step-by-step model for the development of service business and supply chain**

In this paper we analyse two industrial manufacturing company cases from Finland that have developed industrial services. Service-dominant logic defines ten foundational premises as the core of the theory, and we have applied parts of S-D logic for the development of service offerings and deepening of customer orientation. The delivery of goods and services for the manufacturing SME in a global business is a great challenge and we define a framework for service supply chain management. We have created step-by-step service development phases (SDPs), for defining the required steps in the service business development process (Hemilä, 2012). There is a strong link in the development phases to S-D foundational premises.

The development begins with an analysis of the company's present state and its strategy (SDP1). The strategy should be changed from product orientation to service orientation. In this phase, the company should define the services it is aiming for and its value proposition, how they will provide value in the future, and how to act as a part of a service economy. The main strategic concern is the service business opportunity. SMEs might not reach the critical mass needed by the service business to be profitable (Kaski et al. 2011). Gebauer et al. (2010b) outline five generic service strategies to select:

- Customer service: service offerings aim to increase customer satisfaction and strengthen the credibility of the manufacturing firm.

- After-sales service provider: in highly competitive markets with very price-sensitive customers, suppliers offer basic services for the installed base, such as repair, maintenance and overhaul.
- Customer support service provider: concentrating on optimising customer processes, suppliers offer maintenance services, including preventive maintenance agreements, refurbishment and process optimisation.
- Outsourcing partner: when customer interest in reducing the initial investment and operating risks is strong, a supplier can offer operational services and take responsibility for the customer's operating processes.
- Development partner: collaborative innovations can arise from a supplier that offers R&D-oriented services but also pays intermediate attention to after-sales and process-oriented services.

As we focus on manufacturing companies with their own product offering, the selected strategy is somehow a mix of the list above, because with product life cycle service offering, each of these mentioned roles can be addressed. Alam and Perry (2002) have argued that there is a lack of strategic focus on service development and competencies. We suggest that it depends on the customer case as to which kind of role a manufacturer can offer and in that way the strategy with each customer might be different. It is a question of customer segmentation and individual customer requirements as to which kind of service strategy should be selected. A traditional strategy approach sees that value is embedded in the products or services (value-in-exchange) and delivering value means selling to customers, a service strategy focuses on customer experiences and value co-creation in the consumption stage (value in use) (Kaski et al. 2011).

The second step is the analysis of the product offering, its features and value in use, and the mechanisms for service provision (SDP2). For the manufacturers the business is based on the product offering and the service offering support to the product life cycle. There should be a sufficiently installed base to allow services to be competitive (Kaski et al. 2011). Today, embedded ICT and other modern technologies in products are bringing competitive advantage for manufacturers and opportunities for service offerings. Kowalkowski et al. (2013) have argued manufacturing SMEs cannot enter the service market by serving the installed base, because SMEs usually sell through distributors, deliver through installers, and have limited access to their installed base. Our case companies have a direct selling channel to customers and all life cycle services from installation to end-of-life can be offered, but the bigger issue is how to organise a global service offering with limited resources.

The next step is the creation of a service-centred view through customer analysis, new customer segmentation according to the potential service customers and existing customers for sold products (SDP3). A service-centred view means a more customer-oriented approach to business processes and the co-creation of value. The customers should be segmented in order to achieve a better overview of the markets. Usually each customer is willing to be served as a one-segment customer. With generic service offering, it is still possible to create the feeling in the customer that services are tailored just for them. Service-Dominant Logic requires that a deep, long-term development partnership is built with customers and in collaboration with the customers, service innovations and modifications can be elaborated and the company's service portfolio designed in a customer-focused and profitable way (Kaski et al. 2011).

The fourth to sixth step create the service offering together. The fourth step is the analysis and development of a product life cycle model (SDP4). The product is the core of many goods-dominant businesses, but in the S-D approach, goods deliver value in use for customers. Services are developed for supporting the entire product lifecycle (SDP5), and the service offerings can be modular and packed as service packages for the



customer (SDP6). The service offering is produced by the supplier, consumed by the customer and its value is co-created. Korhonen and Kaarela (2011) have noted that many companies aiming to create a new service business stumble in their service innovation efforts as their customers are not willing to adopt the new services. A great number of industrial companies also have difficulties persuading customers to take part in joint innovation practices that are seen as beneficial in the development of new services (ibid.). Kaski et al. (2011) have argued that the main challenges for SMEs seem to be in acquiring a deep customer insight and designing a concrete service concept based on it. We have used customer interviews to achieve a better understanding of requirements and deepening customer insight. Customers have told us which kind of services they are willing to buy and where their own competencies are insufficient. We see that as a co-creation of value and service offering.

The next step is the creation of a service organisation for the company itself or outsourcing a local service near the customer site (SDP7). Resources are the fundamental source of competitive advantage, whether it is the company's own or an outsourced resource, and resources create value as networks of networks (resource-integrators). Organisation, in particular, is really challenging for SMEs selling products worldwide, because the services always need a local presence. It is easy to sell and deliver spare parts globally, but the maintenance operation and all services at the customer site are the most challenging part. S-D logic replaces the concept of a supply chain with a network concept that is referred to as a service ecosystem (Lusch, 2011). We have used the term "service supply chain management" where an organisation should create, operate and follow-up the flows of human resources, materials, financing and information. Most cases are collaboration between two firms, but sometimes there are more firms involved in the service offering. SMEs have difficulties to realise ecosystem thinking in practice, but they would rather talk about the supplier-customer relationship and in that way the service supply chain.

Next, earning logic and pricing models should be created for the services (SDP8). Services create value for the customer, but the question is how much and what kind of value? It is a complicated task to decide how much customers are willing to pay for value-added services (Laine et al. 2004). A key issue for manufacturing firms is their ability to charge for services and the introduction of new capabilities with enhanced offerings through a new value constellation into an on-going business relationship, which changes the status and potential of the customer-provider relationship and can lead to a changed revenue model (Kowalkowski et al. 2013).

A movement from goods orientation to service orientation also requires new models for marketing and sales (SDP9). A product catalogue and technical specification is easy to understand, and it is quite easy to sell concrete products. After all, the parts mentioned above are completed, the company should launch its service offering on the market (SDP10), and, according to feedback and experiences, the service offerings should be updated and improved (SDP11). Table 1 summarises the link between the service development phases and S-D foundational premises.

**Table 1 Service development phases and S-D foundational premises**

	Service Development Phases	S-D Foundational Premise
SDP1	Company present state and strategy	FP1 Service is the fundamental basis of exchange. FP5 All economies are service economies. FP7 The enterprise cannot deliver value, but only offer value propositions.
SDP2	Products and its features	FP3 Goods are distribution mechanisms for service provision.
SDP3	Customers, segments, needs	FP6 The customer is always a co-creator of value. FP8 A service-centered view is inherently customer oriented and relational.
SDP4	Product life cycle	FP3 Goods are distribution mechanisms for service provision.
SDP5	Services along product life cycle	FP1 Service is the fundamental basis of exchange. FP3 Goods are distribution mechanisms for service provision.
SDP6	Service offering, service modules	FP1 Service is the fundamental basis of exchange. FP6 The customer is always a co-creator of value.
SDP7	Service organisation, service processes	FP4 Operant resources are the fundamental source of competitive advantage. FP9 All economic and social actors are resource integrators. FP10 Value is always uniquely and phenomenologically determined by the beneficiary.
SDP8	Earning logic, service pricing models, service value	FP2 Indirect exchange masks the fundamental basis of exchange. FP6 The customer is always a co-creator of value. FP7 The enterprise cannot deliver value, but only offer value propositions. FP9 All economic and social actors are resource integrators. FP10 Value is always uniquely and phenomenological determined by the beneficiary.
SDP9	Service sales and marketing models	FP2 Indirect exchange masks the fundamental basis of exchange.
SDP10	Service launching to markets	FP5 All economies are service economies. FP10 Value is always uniquely and phenomenological determined by the beneficiary.
SDP11	Follow-up and improvements	FP1 Service is the fundamental basis of exchange.

S-D foundational premises require new ways of thinking for traditional manufacturers, so it is not an easy task to implement all ideas from S-D logic in practice. With the step-by-step service development phases, an entire business model can be changed from goods orientation towards a service business. We have used this step-by-step method with two cases in Finland. Both projects took two years with tens of person-months' working time in the companies. We have calculated indexed figures for used resources, time and resource allocation in one of our cases. The company was not willing to share exact man-month figures, so the following figures are indexed. The most challenging part of the development is technology and the product itself, which is quite surprising. There were many people involved in the product development, because they introduced new sensors, ICT and structures to the final product. These developed features created new opportunities for the services, so those were made in close collaboration with the service developers. Services and service modules were next largest tasks.

**Table 2 Resource allocation in service development phases**

		Resources %	Time %	Resource Allocation
SDP1	Company present state and strategy	15	7	10
SDP2	Products and its features	15	14	21
SDP3	Customers, segments, needs	9	11	9
SDP4	Product life cycle	12	11	12
SDP5	Services along product life cycle	12	14	16
SDP6	Service offering, service modules	12	14	16
SDP7	Service organisation, service processes	6	4	2
SDP8	Earning logic, service pricing models, service value	6	7	4
SDP9	Service sales and marketing models	6	11	6
SDP10	Service launching to markets	3	4	1
SDP11	Follow-up and improvements	3	4	1
	Summary	100	100	100

Practitioners using our SDP step-by-step model should have most of the resources at the beginning of the development. Starting from vision and strategy targets and comprehensive customer analysis, they should continue to the development of service offerings. Companies acting in the global business environment should pay special attention to service supply chain management, which is a very challenging task for SMEs.

### Concluding discussion

Manufacturing firms have always delivered services, by supplying spare parts, installing equipment, training employees, or performing maintenance (Kowalkowski et al. 2013). The G-D logic purpose is to make and distribute units of output, preferably tangible (i.e. goods). Goods are embedded with utility (value) during manufacturing and the goal is to maximise profit through the efficient production and distribution of goods. According to S-D logic theory, service is the process of using one's competencies for the benefit of some party, or in other words, service is the application of knowledge and skills. SMEs lack the necessary resources (staff, competencies, facilities and finances) to provide the services that their customers require (Kowalkowski et al. 2013). From the literature, many service development process models can be found, and in the following table we have used Scheuing & Johnson's (1989) analysis and added Grönroos' (1999) approach and our service development phases (Hemilä, 2012).

Donnelly, Berry & Thomasson (1985)	Johnsson, Scheuing & Gaida (1986)	Bowers (1986)	Grönroos (1990)	Hemilä (2012)
Strategic Guidelines ↓	Strategy Formulation ↓	Develop a Business Strategy ↓ Develop a Service Strategy ↓	Analysis and valuation of customer benefits ↓	Company strategy ↓ Product features and lifecycle ↓
Exploration ↓  Screening ↓  Comprehensive Analysis ↓	Idea Generation ↓  Analysis ↓	Idea Generation ↓ Concept Development and Evaluation ↓ Business Analysis ↓	Competition Analysis ↓	Customers needs, Segments ↓
Service Design ↓	Service Design and Process Development ↓	Service Design and Evaluation ↓	Service offering development and testing ↓	Service offering development and testing ↓
Development Testing ↓ Introduction	Testing ↓ Introduction	Market Testing ↓ Commercialization	Market Communication And Follow-up	Service Introduction and improvements

**Figure 1 Service development process models (modified from Scheuing & Johnson, 1989)**

The generic service development process can be presented by the following steps, according to Figure 1 stated above:

1. Strategic level of company: targets, guidelines
2. The corporate environment: idea for services, customers, analysis of business environment
3. The service process itself: offering design and development
4. Implementation, testing, improvement

Each phase consist of several brainstorming sessions, benchmarking, learning, workshops and tens of person-months to realise the service business in practice. Our aim is to test further the service development phases, and we are trying to include more methods and tools to support these phases.

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# TRANSACTION COST THEORY APPROACH IN A SUBCONTRACTOR NETWORK: AN AGENDA FOR EMPIRICAL RESEARCH

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## ABSTRACT

In this paper we present a model to estimate transaction costs in a network of subcontractors and their customers in metal industry. The research questions are: 1) with what kind of a tool could the transaction costs be measured in a network and what is the level of transaction costs (TCs) in metal industry in Finland 2) what factors have a significant effect on TCs in a network, and 3) can TCs be divided into positive, neutral and negative costs.

Keywords: Transaction cost theory, supply chain management, subcontracting.

## INTRODUCTION AND MOTIVATION

This paper focuses on the potential of the transaction cost theory approach in buyer-supplier relationships in the subcontracting metal industry. It presents a method to calculate actual transaction costs (TCs) in a metal industry network, and their division into TC activities. The method includes an estimation of how different factors affect the level of TCs. The paper also aims to start a discussion as to whether the TCs can be divided into positive, neutral and negative transaction costs.

We first present a literature review that identifies the stream of literature which has discussed transaction costs, focusing on literature referring to TCs in networks. Then we describe our research method and conclude with a discussion about the subject.

The importance of managing suppliers has long been recognised among business academics. There is a vast amount of literature dealing with supplier management from both the demand and supply chain management viewpoints. One stream of this literature has focused on transaction cost theory.

A supply chain-wide transaction cost view has featured relatively little in the TC discussion, let alone a network-wide viewpoint. However, the ever-increasing trend in subcontracting also increases transaction costs in supply chains and networks, and emphasises the importance of their management. Subcontracting is increasingly global, and this sets new demands on resources allocated to supplier management. The subcontracting might sometimes be time consuming. There can be a vast need for communication, starting from the negotiation process, and continuing with coordination throughout the cooperation, including communication about specifications, changes, delivery details, etc. The problem has been recognised in almost every company. Figure 1 describes the transaction needs in a network of several suppliers and their customer. The sales and purchasing departments are circled in red (Häkkinen 2011).

In this research, we want to investigate *first* of all the actual level of transaction costs in our case companies. The case companies are part of a real network. Actual TCs have been studied relatively little in TC research. *Second*, we develop a measurement concept to estimate the factors that have an effect on the TCs. *Third*, we start a preliminary discussion about whether TCs can be divided into positive, neutral and negative costs. By this we mean that some transaction costs are actually necessary in order to keep the cooperation fluent between the subcontractor and its customer. Examples of positive TCs could be trust-building activities, or annual meetings where certain important issues are

handled proactively between the parties. Positive TCs could be seen as an investment in the relationship. Neutral TCs cover the normal routines which are necessary for the business to run smoothly. Negative TCs consist of inefficiencies, actions due to mistakes and bad management of the relationship. As a *fourth* phase, we intend to develop tools and mechanisms to help improve the relationship management and to optimise the transaction costs. This fourth subject is outside the scope of this paper.

The framework in this study is contract manufacturing.

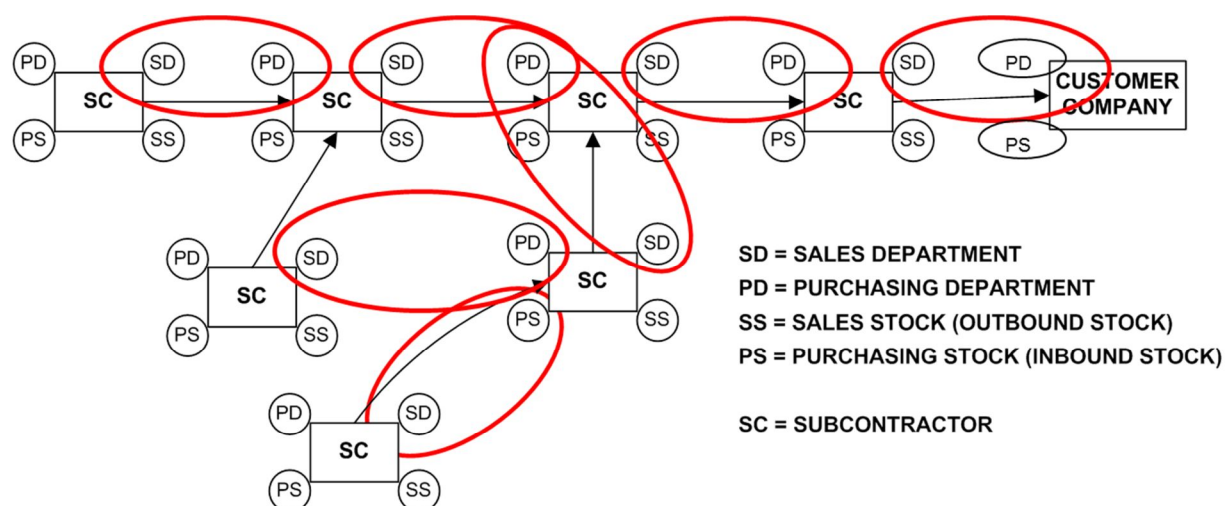


Figure 1: Network level transaction costs (Häkkinen 2011)

## LITERATURE REVIEW ON TRANSACTION COST THEORY

According to Rao (2003), transaction costs are “costs of undertaking a transaction, including search and information costs, bargaining costs and monitoring-enforcement costs of implementing a transaction; and the opportunity costs of non-fulfilment of an efficient transaction”. Transaction costs can be divided into *ex ante* costs and *ex post* costs. *Ex ante* costs comprise the costs of actions before making the actual contract, e.g. negotiating and forming a contract or agreement. *Ex post* costs include monitoring and enforcing a contract or agreement (Rao 2003). One common classification for transaction costs is 1) negotiation, 2) coordination and 3) monitoring costs. We use this classification in our research. Another classification often used is 1) information costs, 2) negotiation costs and 3) monitoring (or enforcement) costs (e.g. Hobbs 1996).

The reason why transactions cause certain costs and why they vary from one situation to another can be explained by dimensions, features and some main factors. The *main dimensions* may be identified as complexity, frequency of occurrence, duration or continuity, uncertainty, measurement and monitoring features, and implications for interlinked transactions. *The features*, which run in parallel to the dimensions, can be identified as asymmetric information and incomplete specifications of transactions and their commitment implications, and imperfect commitment or strategic behaviour (Rao 2003). *The main factors* are bounded rationality, opportunism and asset specificity (Williamson 1985). Bounded rationality is “the assumption that human behaviour is intentionally rational, but constrained by the capacity to process and communicate information” (Simon 1957). Opportunism can be described as “self-interest seeking with a guile” (Williamson 1985). Asset specificity refers to the extent to which non-fungible assets are tied to particular transactions specified by contracts or other commitments (Rao 2003). We have presented these definitions in the figure below.

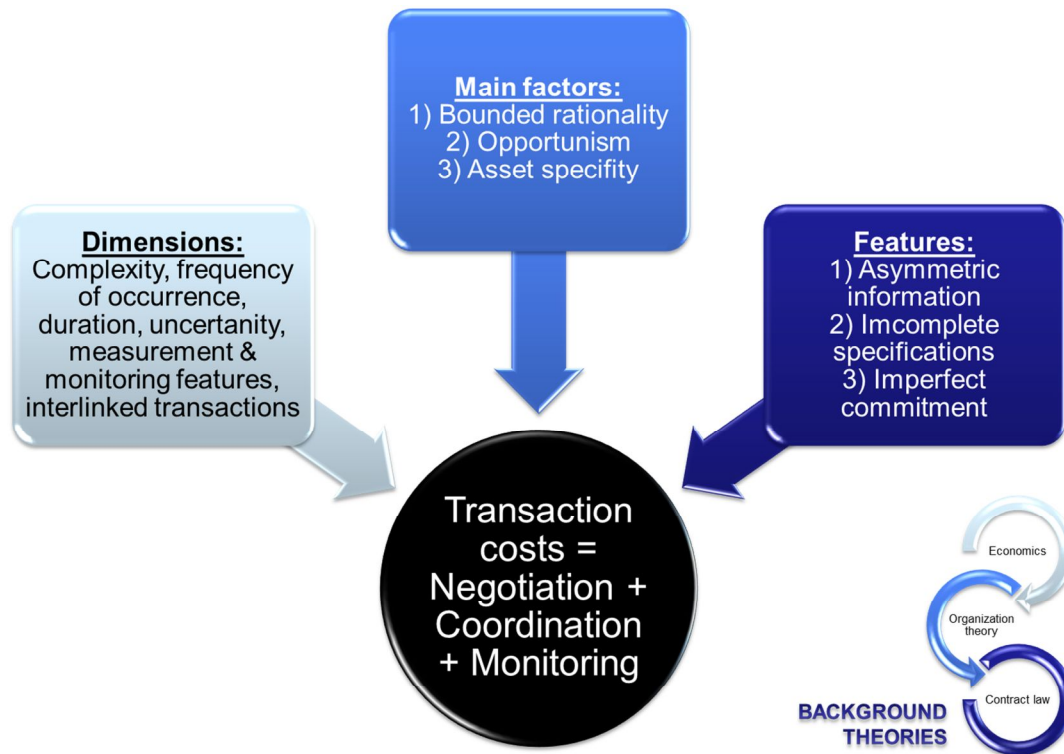


Figure 2: Transaction costs (based on Rao 2003 and Williamson 2007)

Transaction costs have been studied diversely, crossing disciplinary boundaries, including economics, organisation theory and contract law (Williamson 2007). TC theory can be a versatile tool for subcontractor management. It includes economic, behavioural and organisational aspects (Hobbs 1996). In his latest book, Butter introduces a new term called *transaction management* for managing transaction costs in the era of globalisation (Butter 2012). There are some areas, however, in TC theory, which have a need for further research, including from a supply chain-wide viewpoint. TC studies often examine bilateral exchanges (Wever et al. 2012). However, as subcontracting is increasingly becoming an essential part of the business in the manufacturing industry, there is a need for supply chain-wide, or network-wide, research. In the subcontracting industry, the transaction costs can vary significantly from case to case (Häkkinen 2011). In this research we intend to dig into these reasons, taking various parties of the subcontractor network into account.

Another viewpoint that has not been handled widely in TC theory is a profound study of the nature of different transaction costs. There is a need to identify a) which transaction costs act as an investment in good and profitable relationships, b) which costs are essential in order for things to run smoothly, and c) which costs are caused by inefficient processes and poor management. Coase brought this up in 1988 by writing: "Another consequence of the assumption of zero transaction costs, not usually noted, is that when there are no costs of making transactions, it costs nothing to speed them up, so that eternity can be experienced in a split second. It would not seem worthwhile to spend much time investigating the properties of such a world. What my argument does suggest is the need to introduce positive transaction costs explicitly into economic analysis so that we can study the world that exists" (Coase 1988). In this research, we intend to start discovering whether the transaction costs can be divided into positive, neutral and negative costs with the use of empirical data. The case companies are asked to estimate how much the above-mentioned dimensions, features and main factors affect the time spent on transaction cost activities.



## METHOD AND THE RESEARCH INSTRUMENT

The research is conducted as a multiple in-depth case study with constructive case study methodology (Yin 2003). The unit of analysis is the buyer-supplier dyad in contract manufacturing, thus the case companies are three subcontractors and four of their clients (Fig. 3). They are part of the same real-life network. Our intention is to build a model to calculate transaction costs in a subcontractor network. The research questions are:

1. What are the actual transaction costs in the case companies, divided into activities and can a tool for estimating them be developed?
2. How strong an impact do different dimensions, main factors and circumstances have on the transaction cost activities?
3. Based on the above, can TCs be divided into positive, neutral and negative costs? Or further, which cost activities can be seen mainly positive, which neutral and which negative, and to what extent?

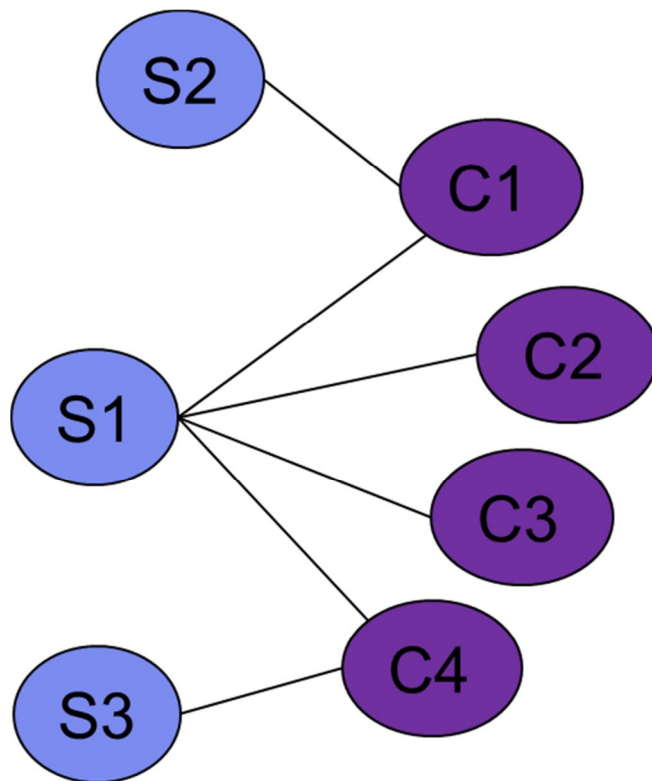


Figure 3: Case company network in the study: suppliers S1-3 and customers C1-4.

In each case company, the matter is first discussed in a preliminary meeting, where typically the managing director, purchasing or sales director and other purchasing or sales personnel take part. Together we determine the persons who will be included in the study. The intention is that all those who have a role in the relationship with the supplier or the customer will take part in the study. These persons include sales, purchasing, R&D and some production staff. Later on in the study, we will broaden the aspect into warehouse operations. After that, those involved are informed about the study. Then they fill out a working time chart where they distribute the working times over one week into various transaction cost activities. They also estimate how much certain dimensions,

factors and circumstances affect the time consumed by each activity. The research instruments are described in tables 1 and 2.

In addition to the data received through the chart, information like turnover of the relationship and total purchases or sales of the case company is researched.

The cost of each TC activity is calculated using the data from the case companies and using cost data based on our previous research on activity-based costing (Aminoff et al. 2002). In our previous research we performed activity-based costing in about 200 companies.

Five of the case companies are small and medium-sized metal industry companies from Finland, which produce high technology and high quality products. The two others are large, globally operating companies – the branches participating in the study are situated in Finland, but the customer companies operate globally.

The analysis based on the data also includes analysis of the effect of dimensions, features and factors on the time consumed in each TC activity. Through this analysis, we also hope to be able to draw conclusions as to which TC activities can be seen as positive TC costs, which neutral and which negative. We also hope to be able to estimate the proportion of each of these three, as well as some conditions and explaining factors for this. We hope to be able to provide some answers to the question “What is the right level and content of transaction costs in certain situations?”

Hours related to supplier 1	Date:									
	Mon		Tue		Wed		Thu		Fri	
	Hours	Min	Hours	Min	Hours	Min	Hours	Min	Hours	Min
<b>TC1 Negotiation</b>										
Proposal requests										
Negotiations and contracts with the supplier										
Cooperation with R&D departments (own, supplier's and customer's)										
<b>TC2 Coordination</b>										
Order handling and payments										
Contract maintenance and updates										
Taking care of running matters (excluding problems and corrective actions)										
Taking care of matters due to problems, misunderstandings etc. (e.g. in documents and shipments)										
Improving cooperation with the supplier (proactively)										
Documentation (e.g. material documents)										
<b>TC3 Monitoring</b>										
Shipment monitoring										
Quality control and corrective actions (partly in the warehouse or in logistics)										
Reporting and monitoring										
Monitoring own investments at the supplier										

Table 2: Working time data collection chart

Please estimate on scale 0-5 the effect of factors below on the workload for each supplier, 0 = no effect, 5 = increases the workload significantly.	Supplier 1	Supplier 2
Dimensions		
Complexity		
Frequency of occurrence		
Short duration of the relationship		
Uncertainty around the transaction (e.g. supply and price uncertainty)		
Poor measuring possibilities (e.g. supply capability)		
Interlinked transactions (e.g. to other departments of the company)		
Features		
Asymmetric information		
Incomplete specifications		
Imperfect commitment of the partner		
Main factors		
Bounded rationality		
Opportunism		
Asset specificity		
Other?		

Table 2: Effect of factors on the workload

## CONCLUDING DISCUSSION

With the help of the literature review, important research needs related to the issue of transaction costs have been identified, and the research has been directed to fill part of this gap. This study aims to give answers to questions about some practical issues, such as how time consuming is subcontracting really? What is the actual level of transaction costs compared to the turnover of the relationship? What part of the TCs can be seen as an investment in the relationship? Which factors affect the level of TCs concerning the rest of the transaction costs, which we have named here neutral and negative TCs? How significant a role do poor information, poor specifications, short-term relationships or complexity play, for example?

We will continue from here with the actual analysis based on the data. We already have in mind some further research issues based on discussions made so far with the case companies and the literature review. The research needs include an extension of this model outside contract manufacturing, where behaviour differs from contract manufacturing. Another important issue seems to be to investigate the relationship between transaction costs and warehousing costs. As far as we can determine, research into the interaction of coordination costs, which occur after making the contract, with warehousing costs, does not exist. In industrial companies, purchasing personnel have woken up to the fact that managing suppliers, especially after making the contracts, is very time consuming, and all that work most probably is not included in the formulas which determine the optimal order points. How do current KPIs direct operations? Is there a need to introduce some new KPIs? Do the current KPIs perhaps only lead to short-term optimisation? We intend to address these issues in our future research.

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**POSSIBLE SUPPLY CHAIN AND MARKETING PRACTICES  
FOR LESS COMPETITIVE PRODUCTS:  
A CASE OF THAILAND IMPORTING AGRICULTURAL PRODUCTS FROM  
CHINA**

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**INTRODUCTION**

The free trade agreement between Thailand and China has resulted in the increase of international trade, both in terms of export and imports. However, this consequently leads to intense competition of entrepreneurs in related sectors. It has been witnessed that Thai agricultural products are less competitive to Chinese agricultural products, which results in an increase in Thailand importing these products from China. With accordance to the economic theory, many countries have engaged in trade liberalization with a prospect assumption that, at the macro level, the "greater good" will result through specialization. Yet, at the micro level, it is possible that stakeholders of less competitive products, especially in term of production costs, may tremendously suffer. Though it may be argued that this is a process of achieving the national specialization and competitiveness in the long-run, short-term solutions to these stakeholders should be implemented to absorb the effects. The primary aim of this paper is to use the experience of Thailand in importing agricultural products from China as an example to provide possible supply chain and marketing practices which can be used to attenuate the negative effects on less competitive products. By this, the paper also assesses strengths and weaknesses of each party, as well as compare and contrast practices between these two countries.

**BACKGROUD INFORMATION**

This section provides relevant background information of this study. According to Zamroni (2006), Thailand has been the most active country in Asia with regards to its involvement in FTAs, especially, the agricultural sector which plays an important role in promoting the Thai economy and the government has opened up the sector to international international competition. In regards to trade relation with China, Thailand has restored trade relations with China in 1976 after the official restoration of diplomatic ties between the two countries in 1975 (Roernmahasarn, 2003). After Thailand signed FTA with China, which would result in fruit and vegetable tariffs becoming zero in year 2004, many economist and people were afraid of this establishment. Pongjityingyong (2007) showed that, after the agreement, even though Thailand's export to China increased dramatically, its imports from China is increasing even more. However, the recent international trade records have shown that, at the macro level, Thailand benefits from such trade agreement as Uthaisangchai (2005) summed up that agricultural trade is running strongly in favour of Thailand where as in terms of export as a whole, the trade balance is narrowing.

Yet, at the micro level, there should be practices to absorb negative economic or even psychological effects on entrepreneurs. For example, a couple of arguments between

decision and local farmer's opinion was described by Pongjityingyong (2007) as: 1) A number of Thai agricultural products will become vulnerable; 2) Some Thai farmers are unwilling to allow China to ship fruits and vegetables into the country for the fear of the unfair trade.

## **METHODOLOGY**

This study uses qualitative and quantitative techniques to collect data from both primary and secondary sources. To detail, at the beginning of the study, the authors use secondary sources to aid the conceptualization of underpinning framework of practices when trading less competitive products. Also, this helps the authors grasp the whole picture on past issues and the current situation in agricultural trading, in general, and more specific between Thailand and China. Then, the authors proceeded to gather information from primary sources. Mainly using the mixture of in-depth interview and focus group interview, the authors collect information from two main parties; that is, the public and the private parties. In regards to the public parties, the researchers interviewed government officers from departments and ministries related to international trade and trade policies (for example, Thai commerce ambassador in Kunming) whereas the private party participated in this study includes exporters, importers, middlemen (for example members of Chamber of Commerce) who have been experience in agricultural trading between Thailand and China. In addition, the researchers made several study trips to China to gather information in regards to the wholesale system of agricultural products and the logistics system. In addition, this study gathers information from consumer behavior perspective in order to shed light on possible marketing practices. By this, the questionnaire survey was employed to collect such information.

## **RESULTS AND IMPLICATIONS**

It is revealed that China, in relative to Thailand, is more competitive in terms of production of agricultural products with primary advantages being low costs, high productivity, and favorable government policy. Negative effects were amplified for many Thai farmers those with cooler growing climate condition similar to China, such as garlic producers in the North part of Thailand. This sections highlight the strengths and weaknesses of each country as well as present possible supply chain and marketing techniques that could be used when the home agricultural products are less competitive. (Supawadee ,2010)

### **Strengths and weakness of Thailand**

The main strength of Thailand in the context of Thailand-China agricultural products is production technology that enables farmers to year-round grow popular vegetables and fruits in the Chinese markets. This enhances prices of agricultural products. However, Thailand has weaknesses in terms of high costs of production and that the agricultural products are easily perishable due to the tropical climate condition. Also, the logistics system in Thailand is not well interlinked yet, especially the rail mode of transportation which increase the overall costs of agricultural products.

### **Strengths and weakness of China**

In China, there are two systems of the vegetables and fruits production namely; (1) mass production (such as garlic, carrots and apples) which establishing regulatory associations which were supported by the Chinese government and managed by private sectors (2) the production of general farm (for example the different types of vegetables from Yunnan) which was encouraged the production and export by the Chinese government.

Strength analysis showed that firstly, the wage levels in China are low relative to industrial countries, as the result, products made in China had strong international competitiveness. Secondly, there were many productivity areas for agriculture

developing in China. Thirdly, the Chinese government's policy supported farmers and exporters in systematically. On the other hand, the country still had plenty of weaknesses. Firstly, the Chinese trading system was weak and not ready to trade liberalization because the rules of doing business in China were different in each area. Secondly, logistics companies in China were still not linked to the whole network. Thirdly, the very cold weather was not suitable for growing tropical fruits such as durian, mangosteen, and rambutan which were the most imported Thai fruits to China. In the view of China opportunities, China were beneficial from trade liberalization and Chinese temperate fruits which can be fresh collected over long years. Furthermore, Chinese traders also profited from playing their significant roles in importing and marketing management throughout the supply chain. In contrast, the barriers of Chinese were (1) water transportation from China to Thailand had shallow channel problem and (2) dam construction in China created the decreased amount of water in the Mekong. Table 1 provide a compare strengths and weaknesses of Thailand and China regarding exportation/importation in the agricultural sector.

**Table 1:** Comparison between Thailand and China's exportation/importation

	<b>Thailand</b>	<b>China</b>
<b>Exportation/ Importation</b>	<ul style="list-style-type: none"> <li>• The transportation time from Thailand to China takes around 3 days via Mekong River</li> <li>• 1 day custom clearance process for Chinese agricultural products entering Thailand</li> <li>• Thai government covers all inspection costs for Chinese agricultural products entering Thailand</li> <li>• No VAT (Value Added Tax) on Chinese agricultural products entering Thailand</li> </ul>	<ul style="list-style-type: none"> <li>• The transportation time from China to Thailand takes 1 day via Mekong River</li> <li>• Custom clearance process takes several days</li> <li>• Thai exporters have to responsible for all the inspection costs</li> <li>• 3 percent VAT on agricultural products entering China</li> </ul>

**Possible policies for the government**

As an open developing country, Thailand should notice the importance of its agricultural sector and also adequately distribute wealth and benefits to its farmers. In order to maximize the potential benefits of FTAs and minimize the possible negative impacts, the Thai Government needs to satisfactorily make the necessary adjustments to its economy and develop the competitiveness of its enterprises in emerging free markets (Zamroni 2006). Using value chain analysis framework, this study suggests possible polices for the governments as follow:

- The government should seriously consider the practice of inbound logistics of custom clearance at the border of agricultural products from China. By this, the government should consider placing treatment that are similar when the domestic incumbents exports to China. This is not to thwart the import, but to obtain fair practices in international trade between the two countries.
- The government should also conduct market research and educate local farmers or enterprises to understand the need and wants of Chinese market which may lead to new tailor forms of agricultural products that are preferred by such market.
- Strict inspection may also be placed to eliminate agricultural products that are below the consumption standards from entering Thailand.
- The Negotiation committee established by the government to oversee the issues should place importance in outbound logistics of Thai agricultural products.

Especially, FTA should have comprehensive coverage and depth, and include non-tariff barriers, investment, human resources development, intellectual property rights protection and the environment.

- The development of infrastructure; especially in the mode of water and rail transportation should be taken seriously to attenuate export logistics costs of Thai agricultural products.
- The government should also focus on strengthening the production/operation of the domestic farmers especially, in terms of productivity, efficiency, and international competitiveness.
- In regards to Thai consumer, campaign for Thai vegetables without chemical and pesticides may be made to increase awareness and concern of low price import agricultural products.

#### **Possible practices for entrepreneur**

- Since several Thai agricultural products are less competitive in its origin form (i.e. raw materials), Thai enterprises should add value to the raw agricultural products. The Office of Creativity Economy of Thailand may be a good starting point to gather ideas on product development.
- The use of productive and innovative workforce through training and investment in knowledge, skills.
- Follow the technological upgrade and knowhow; especially, from the Royal Projects which normally provide low cost solutions to enhance productivity

#### **CONCLUSION**

From the macro perspective, trade liberalization would result in higher productivity and specialization which consequently bring benefits to the society. At the micro level, preparations should be placed to aid the producers of less competitive products. By using the experience of agricultural trade between Thailand and China, this study provides several practices for both the policy make and the entrepreneurs to attenuate its negative effects on local enterprises.

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# **IDENTIFYING LOGISTICS STRUCTURES – A HOLISTIC FRAMEWORK FOR THE ANALYSIS OF STRUCTURAL DESIGN OPTIONS FOR SUPPLY CHAINS**

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## **The Understanding of Organizational Structure in the Literature**

There are indicators for the assumption that logistics structures have a significant influence on the performance of logistics systems. This shall be exemplified by the organisational principle autonomous cooperation, which describes processes of decentralised decision-making of autonomously interacting logistics objects (Windt, Hülsmann 2007). Referring to contingency theory-based descriptions of organisational structures, e.g. through the variables specialisation, standardisation, formalisation, centralisation and configuration (Pugh, Hickson et al. 1968), in terms of degrees of order (Cordes 2013), high degrees of autonomous cooperation are positively correlated with low degrees of order in logistics systems. Consequently, the degree of autonomous cooperation can be represented by an overarching understanding of organisational structures through associated variables, developed from contingency theory (e.g. Burns, Stalker 1961, Lawrence, Lorsch 1969).

Furthermore, simulation studies showed that autonomous cooperation affects the robustness of logistics systems (Hülsmann et al. 2009), and it contributes to companies' strategic adaptivity through balancing between flexibility and stability (Hülsmann et al. 2008). Hence, when changing the degree of autonomous cooperation in logistics systems changes their organisational structures, and when the degree of autonomous cooperation in turn affects the logistics systems' performances, then the following hypothesis can be deduced: When the structures of logistics systems are altered (e.g. through applying technologies such as RFID), then the logistics performance is affected. However, one central critique of contingency theory-based descriptions of organisational structures is that they differ significantly from each other, which raises the assumption that they use eclectically chosen variables and that they reflect only a small excerpt of the organisational reality (Cordes 2013). For instance, the above-mentioned variables used by Pugh, Hickson et. al (1968) ignore variables such as coordination used e.g. by Grochla (1995), Kieser, Kubicek (1983) or Jones (2004). In consequence, the structures of logistics systems cannot be fully described up to now in a holistic and unified way. Therefore, it is not possible to compare the structures of different logistics systems with each other. This questions the validity and reliability of associated empirical studies and makes it difficult to predict effects of structural changes of logistics systems on performance measures such as the achievement of logistics goals. Consequently, associated research has to go one step back and develop a holistic descriptive model of logistics systems' structures in order to be able to identify those variables that are affected, e.g. when technologies such as RFID are implemented. Only then, it would be possible to investigate the underlying effects in depths, so that managerial implications can be deduced. Hence, the research question of this paper is the following: How can logistics systems' structures be described in a unified and holistic way so that different logistics systems can be compared with each other regarding their structural designs?

One concept that enables integrating most hitherto understandings and concepts of organisational structures and their variables into one overarching terminological system was developed by Remer (1989,2005) (Cordes 2013). This paper attempts to apply Remer's (1989,2005) terminological system to the description of logistics systems. The resulting descriptive model of logistics structures shall provide an operationalization, with which different logistics structures can be compared and hence, empirical studies on their effects can be conducted. Additionally, the contributions and limitations of such a

descriptive model for the analysis of logistics systems' structures shall be investigated, so that implications for further empirical as well as conceptual research can be deduced.

### **Transferring a Terminology of Organizational Structure to Supply Chains**

The question how supply chains can be described and designed refers to the instrumental understanding of organization, which can be understood as e.g. *"the entirety of measures taken to achieve purposes and aims, with which a social system is structured, and with which activities of the people pertaining to this system, the use of input factors, and the processing of information is structured"* (Hill, Fehlbaum & Ulrich 1994, p 17). Following this understanding, Remer (1989) states that the main difference between organization structure and process planning is that the planned events are still a floating, undifferentiated sequence, which has to be decomposed (i.e. structured) with respect to its mediums (i.e. people or tangible means) into different roles. The importance of this distinction is also highlighted by Aiken, Bacharach & French (1980, p 634) who state that *"the failure to distinguish between structures and processes and the consequent treatment of the latter as properties of the organization per se has resulted ,methodologically, in [...] highly misleading empirical results"*. Hence, based on the understanding of organizational structure by Remer (1989, 2005), Cordes (2013) defined organizational structure as follows: *"Organisational structure is a system of regulations aiming to steer the behaviour of the members of an organisation."*

According to Röder (2001), realizing complex tasks in labour divided processes results in interdependencies and relationships between the different groups involved in the process. By dividing processes in functional fields, interfaces are generated between these fields (Brockhoff 1989). In order to achieve the overall goal, the fulfilment of these sub-divided tasks has to be coordinated across these interfaces (Röder 2001).

Organizational entities do not necessarily belong to the same company, but also supply chain partners, who are dependent on suppliers and customers, can be considered. This definition can also encompass different departments or locations of the same company. This is also stressed by Brown (1983, p. 1), who states that these entities (or social units) *"may be groups, departments, or whole organizations, and their contact may be recurrent and well-established or fleeting and episodic"*. Thus, interfaces do not only occur in companies, but also on the supply chain level, and interactions may be on ad-hoc as well as long-term bases.

According to this understanding, the terminology used in the context of organizational structures of companies also seems to be applicable to supply chains in general by changing the level of analysis from a company focus to a supply chain perspective. In organizational theory, there exists a large body of literature on variables to describe the structure of an organization. The division of labour, which can be seen as a main cause of having several companies connected by a product flow in supply chains, is also a major variable of organizational structures, as addressed in the literature on organizational theory (e.g. Hall 1963; Remer 1989; Grochla 1995; Greenberg 2005; Thom 2010). However, apart from the division of labour, a multitude of variables exist to describe organizational structures (Remer 1989). The question is which variables to use. In order to enhance the general validity of statements (e.g. Chmielewicz 1979), the variables should be able to describe not only the organizational structure of organizations, but also organizational structures of socio-technical systems in general.<sup>2</sup> This would allow the expansion of the terminology to supply chains. Furthermore, the variables have to be exhaustive, to describe supply chains completely, and mutually exclusive, too avoid redundancies (Chmielewicz 1979).

One approach that seems to fulfil these requirements is the terminological system of organization provided by REMER (1989, 2005), due to several reasons. Firstly, it is

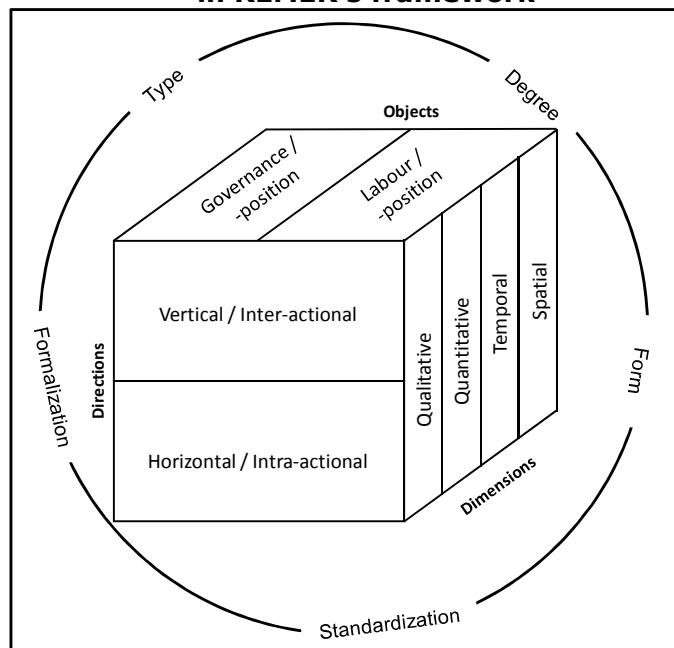
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<sup>2</sup> Companies can be basically understood as combinations of mechanical and human resources and therewith as socio-technical systems (Hülsmann 2002). However, the term socio-technical systems can also be applied to larger systems, such as supply chains (Clegg 2000).

general, since the descriptive system is not only used to describe organizational structure, but also planning, potential, and policy. Secondly, many variables used to describe organizational structures in the literature are specifications of the two main components of organizational structures (Remer 1989). Finally, it is specific, as the elements can all be divided into smaller entities of interest and filled with content depending on the focus of interest. Therefore, the organizational structure of supply chains shall also be described with REMER's terminology.

Organization can thereby be understood as "a system of roles, which is constituted by purpose-oriented (instrumental) expectations" (Remer 1989, p. 2). How the system of roles is structured, i.e. how each role is defined in the context of other roles and the overall system, depends on decisions regarding the organizational *differentiation*. The second variable is *programming*, which refers to the formulation of purpose-oriented expectations posed on a role. The descriptive decomposition of these objects into further sub-elements of analysis, which all might be manipulated for the purposeful design of supply chains, can be found in Figure 3.

**Figure 3: Systematic decomposition of variables of organizational structure in REMER's framework**



In the following, the variables differentiation and programming shall therefore be considered and systematically described by transferring REMER's system to supply chains.

### **Differentiation of Organizational Structures at Interfaces in Supply Chains**

As stated above, *differentiation* refers to the definition of roles in a system (Remer 2005). More specifically, organizational differentiation has been defined by Cordes (2013) based on Remer (1989) as follows: "Organisational differentiation is the quantitative, qualitative, temporal and spatial horizontal as well as vertical decomposition of labour and governance into positions and instances (governance positions)." If the system is now considered to be made up of different companies, which produce a service or product in labour division for the market, the objects represented by these different positions change from a single organization perspective into a multiple organization perspective. In consequence, horizontal and vertical labour and governance positions have to be defined for a supply chain context.

*Objects* of differentiation in a social system are *labour* and *governance*. Whereas labour refers to the execution of work processes, governance refers to the control and monitoring of work processes (Remer 1989). In supply chains, as different legal entities come together, in general each entity unites both objects for its part of the supply chain. Thus, a differentiation would not be necessary. However, if one considers outsourcing of activities to sub-contractors, such a distinction becomes useful, as the outsourcing company (i.e. the principal) could be held responsible for the performance of its sub-contractor (i.e. the agent) by the other partners in the supply chain. Therefore, governance positions are here understood as principal positions, whereas labour positions are understood as agent positions.

These can be further specified regarding the *directions* of differentiation. Directions of differentiation can be *vertically* and *horizontally* oriented, but focus on the chain of command instead of the chain of processes. The organizational layers can be further specified regarding the dimensions *quality*, *quantity*, *time*, and *space*. In order to avoid redundancies and to keep the description short, examples for the transfer to supply chains will be primarily given for differentiation of governance or of labour.

The *vertical differentiation of governance* refers to the gradation of authority to issue orders. It divides positions in a system according to making commands or receiving commands (Remer 1989, 2005). For supply chains, vertical differentiation of governance would thus answer the question, to what extent processes have been outsourced, thus how many tiers are involved in the provision of the final product. In the case of strategic networks, this could mean for example that more tiers are involved in the supply chain, as the principal-agent risks normally associated with outsourcing are reduced.

*Horizontal differentiation of governance* reflects the division of authority on the same level, i.e. between units (Remer 1989). Whereas division of labour has been frequently regarded as a measure to increase efficiency (e.g. Smith 1791), division of authority is a less analysed aspect. In the context of supply chains, the companies decide on the share of responsibility for the production of the final service or goods. Notwithstanding whether they produce themselves or decide to outsource partly or completely production, each of these principal companies has responsibility for monitoring and control of the workflow.

The dimensions *quality*, *quantity*, *time*, and *space* differentiate work and authority further regarding their content, amount, and temporal-spatial allocation (Remer 2005).

In a *temporal* sense for instance, vertical differentiation of governance defines the phases in the chain of command (Remer 1989), for example into having authority during capacity planning in the supply chain versus during execution of activities. *Spatially*, vertical differentiation of governance would divide the authority depending on levels, such as global authority versus local authority (Remer 2005). For horizontal differentiation, authority could be differentiated regarding locations, if offices for example exist at several places. This may be for example the case if companies integrate vertically in order to obtain better control over suppliers and to enhance traceability of food products (Jaffee & Masakure 2005).

As already mentioned above, vertical and horizontal differentiation of governance is further specified by the characteristics *type*, *degree*, *form*, *formalization*, and *specialization* (Remer 2005). However, whereas type, degree, and form further describe and specify the organizational structure, formalization and specialization take a kind of intermediate form, as they do not describe organizational structure itself, but its general validity (Remer 2005). Regarding *type* of differentiation, it could be oriented more towards the requirements of the planned governance programme, or more towards the existing potential of the governance system (Remer 1989). For supply chain partners, the horizontal and vertical governance structure would then be either differentiated based on the requirements of the planned transaction, or based on the available tools and methods for issuing commands (e.g. by automatic order picking), and for controlling their execution (e.g. by shipment tracing). Furthermore, the type of governance differentiation can be used to further specify the quantitative, qualitative, temporal, and spatial dimension of governance differentiation (Remer 1989).

The *degree* of vertical and horizontal differentiation refers to the question, how intensive (i.e. segmented) and how extensive (i.e. fragmented) for example the governance structure of the system is differentiated. *Segmentation* regulates hereby the (dis-) similarity of units or levels,<sup>3</sup> whereby *fragmentation* defines how many units or levels of the same kind exist (Remer 2005). Each of the two can be either high or low, and are not completely separable, as there exists a trade-off between them (Remer 1989). Supply chain partners could for instance decide that there is only one unit (i.e. low fragmentation) issuing all kinds of commands for the execution of supply chain processes (i.e. low segmentation). However, this configuration would result in a huge complexity and amount of tasks, which could not be handled appropriately. Additionally, Remer (1989) stresses that the configuration of the degree of differentiation may depend on the situation. Furthermore, he adds that a high degree of differentiation in one criterion (e.g. vertical authority grading) can be partly compensated by a low degree in another criterion (e.g. horizontal authority distribution).

The *form* of differentiation refers to whether the system of roles is a manifestation of a fixed perception of the system and its purpose (i.e. inward-oriented or system-oriented), or whether the system has been designed in response to environmental conditions and constraints (i.e. outward-oriented or environment-oriented) (Remer 2005). For instance, is the differentiation of governance of an interface an expression of the purpose of the interface (e.g. cost-efficient transactions)? Or is it the expression of environmental constraints (e.g. compliance with regulatory requirements)?

An organizational structure is *standardized*, if and in so far it is fixed in the long-run (Remer 2004). The degree of standardization incorporates thereby two aspects, firstly, the *temporal durability* of fixation, and secondly, the validity *without exception*. For vertical and horizontal governance differentiation, standardization refers to the temporal duration of rules. However, as in the case of other characteristics described above, not all aspects have to be standardized to the same extent (Remer 2005). In the case of interfaces, supply chain partners may fix for example the structure of the chain of command (i.e. vertical governance differentiation) for all transactions ever to be done (i.e. durability and without exceptions), whereas the number of involved units (i.e. horizontal governance differentiation) can vary for sub-sequent transactions or depending on the products transferred (i.e. durability and exceptionlessness). If for instance perishable food products are transferred, it may be important to always involve apart from the logistics department also the quality management department, whereas this may not be necessary if the same partners transfer e.g. dry solids (i.e. high temporal durability, with exceptions).

Finally, differentiation of governance can be formalized, receiving validity for a group of roles (i.e. *socio-spatial infinity* of validity) and being more or less compulsory (i.e. *rigidity* of validity) (Remer 2005). Therewith, *formalization* helps in making random rules to universally valid rules (Remer 2005). In fact, in supply chains, formalization is frequently regarded as a crucial aspect of successful collaboration (Min et al. 2005). This is especially important for instance in international food supply chains, where partners of different cultural backgrounds with different habits and social rules have to agree upon the design and execution of transactions. As such, they might perceive risks differently and follow different implicit models of relationships (Canavari et al. 2010). Thereby, the formalization of rules by e.g. explicit and extensive contractual agreements refers to the binding nature of the agreed-upon governance structures, and the fixation of penalties helps to assure that both partners will not deviate from the contract.

Considering these different aspects, it can be observed that they all provide continua of possible designs. If one combines then different manifestations of each characteristic with each other, an abundant array of combinations of governance differentiation arises (Remer 1989, 2005). Even if only the end points of the continua would be regarded, numerous options would be possible.

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<sup>3</sup> Similarly, Frese & Beecken (1995, p 135) define segmentation as "*horizontal de-composition [...] by creating coequal parts*".

## Programming of Organizational Structures in Supply Chains

According to Remer 2004, organizational programming has to be differentiated from program planning, since the latter refers to the creation of plans, whereas the former refers to the transfer of plans into role expectations (i.e. instructions). Hence, whereas operational planning refers to the content of work (i.e. *what* has to be done), programming refers to the way of working (i.e. *how* something has to be done). In accordance with Cordes (2013), organizational programming can be defined as follows: "*Organisational programming is the assignment of quantitative, qualitative, temporal and spatial instructions on intra- as well interactional activities to positions and instances.*"

Thus, whereas differentiation has the purpose to create capacities, programming of roles has the purpose to control. Remer (1989) differentiates the programming of governance positions and labour positions regarding their task program (i.e. *intra-actional programming*) and their cooperation program (i.e. *interactional programming*).

Thereby, *intra-actional programming* of governance positions answers the question, how the exhibitor of a leadership role shall effect its regulating function, thus, which methods to use for governing (Remer 1989). In analogy, labour positions are programmed regarding which activities they are expected to complete. In contrast, *interactional programming* refers to specifications of interaction, hence how a position is instructed to cooperate with other positions. In the context of supply chains, partners could for instance determine that interaction between principals and agents requires more specification, if new technologies are used for the first time, or if products or processes are highly sensitive towards disturbances. Furthermore, the supply chain partners might agree on a regular meeting or information exchange between managers on managerial practices. In the food and retail sector for instance, this might include quarterly meetings, where customer demand, new product development, in-store display support, cost-benefit analyses of inventory holding versus direct shipping etc. can be discussed (Min et al. 2005). Another example for such reciprocal, continuous and structured exchange of knowledge and information are communities of practice, which emerge in long-term exchange relations of several partners (van Baalen et al. 2005).

Intra-actional and interactional programming can be further described along the four dimensions *quality*, *quantity*, *time*, and *space*. As governance and labour positions can be described in the same way, governance and labour positions are used interchangeably.

The *qualitative intra-actional programming* of governance positions determines which methods to use (Remer 1989). For instance, principals in supply chains could agree to set targets for agents, e.g. by using a defined set of Key Performance Indicators (KPI), instead of giving detailed instructions on how to perform a task. However, the use of different KPIs has been identified as an issue in collaborative supply chain performance improvement, since the use of diverging KPIs may result in conflicts between supply chain objectives (Cai et al. 2009). Therefore, not only the type of methods has to be agreed, but might need further specification.

*Qualitative inter-actional programming* of governance positions instructs for cooperative requirements (Remer 1989). In a supply chain context, principals could among others agree upon, how intended changes to the way of guiding agents have to be communicated and settled between companies. The alignment of methods of instructions between superiors fosters unity of command, avoiding the emergence of incompatible orders or incompatible expectations of behaviour (Rizzo, et al. 1970). Nevertheless, unity of command might be more complicated in supply chains in so far, as the partnering organizations would allow for discretionary power over each other's agents.

*Quantitative intra-actional programming* of governance positions refers to the amount of governance executed (Remer 1989). As such, for example the frequency of controlling the achievement of targets could be fixed, as well as the determination of fault tolerance in the compliance with instructions. Since in supply chains, mutual interdependence may

exist across many stages of the supply chain, such agreements could foster trust in each other's control mechanisms and performance.

*Interactional, quantitative programming* of governance positions defines the extent of cooperation in governance (Remer 1989). This aspect is frequently regarded in supply chain management literature, since it involves for example decisions on the extent of information sharing between supply chain partners, which is frequently seen as a performance driver (e.g. Steckel et al. 2004; Seuring 2004; van Baalen et al. 2005; Bechini et al. 2008). However, thereby mostly no distinction between different hierarchical levels of supply chain partners is considered, which highlights again the need for further differentiation of organizational structures in supply chains.

One example for *temporal intra-actional programming* is the determination of points in time for the execution of governance tasks, or the determination of time-based pre-conditions of decisions, such as due dates. Regarding *temporal interactional programming*, governance positions have to decide on when to cooperate (Remer 1989). Partners in food supply chains for instance agree on allowing facility inspections by the partner in random intervals (Hobbs et al. 2002). Especially for Just-in-Time production networks, not only the specification of when a production step has to be finished, but also when the output of this step has to be transferred is important.

The *spatial intra-actional programming* of governance positions refers to the question of where the control and guidance tasks have to be effected (Remer 1989). Especially in international supply chains, where companies are transporting goods from and to different locations, principals and agents can be at faraway places. Furthermore, where the orders are issued depends for the design of interfaces also on the agent regarded.

The *interactional spatial programming* in turn defines the places or the spatial pre-conditions for cooperation (Remer 1989). Supply chain partners may for instance decide to cooperate only in certain regions of the world. Another important question is also the range or borders of authority between them. As an example, South African fruit and vegetable exports to Europe are frequently based on Free-on-Board (FOB) terms, which means that the buyer takes over responsibility for the product upon loading on the vessel (Ortmann 2005). In this case, the border of authority over decisions on the handling of the product would end for the seller upon loading, where the authority would be transferred to the buyer (as far as the authority of the shipper is not concerned).

The *type* of interactional and intra-actional programming of governance positions can be either oriented towards the conditions of programming, or towards the intentions (Remer 1989). *Intentional programming* would be based on certain rules or regulations, which would be applied irrespective of the case at hand (Remer 2004). For example, the EU regulation (EC) No 852/2004 on the hygiene of foodstuffs prescribes food business operators to implement procedures following HACCP<sup>4</sup> principles. *Conditional programming* would rather determine the aspects, which have to be considered in the situation-specific decision-making (Remer 2004). For example, governance positions in food supply chains would have to consider the product-specific requirements in terms of temperature and relative humidity in their decision-making on transport modes to be used. The type of programming can be specified not only for interactional and intra-actional programming, but also in each dimension, namely for the quantitative, qualitative, temporal, and spatial programming of governance positions (Remer 1989).

The *degree* of programming of governance positions can be again either high or low. It is *extensive*, if all components of the entity are explicitly characterized (such as technical, administrative, and disciplinary expectations). One example: If for every instruction of agents, or every kind of interaction with the partner, not only the outcome expectations were fixed, but also expectations regarding behaviour of principals were defined. Especially in international supply chains, extensive interactional programming might help to overcome the frequently observed inter-cultural and language barriers (Long 2004). A high *intensive* degree of programming is obtained, if every task of the entity is explained

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<sup>4</sup> HACCP is the abbreviation for Hazard Analysis and Critical Control Point. For further reading, see e.g. Mortimore & Wallace (2000)

in detail (Remer 1989). This is for example the case for contingency plans, which are used frequently in supply chains to reduce risks.

The *form* of programming can be inward-oriented or outward-oriented (Remer 2004). However, in contrast to the form of differentiation, the form of programming does not refer to environmental and system perspective, but rather to the position-orientation and organization-orientation. It is *position-oriented*, if each entity is programmed based on expectations associated with this position (Remer 1989). For example, the position "Quality Manager" is expected to be an expert on quality management in its business unit (Saraph, Benson & Schroeder 1989). It is *organization-oriented*, if the programming is based on fixed expectations of the structural organizational context, such as joint problems, interdependencies, etc (Remer 1989). Examples are production teams, which work across conventional organizational boundaries relative autonomously to achieve a joint outcome (Cohen & Bailey 1997).

By *standardization*, the instructions of governance positions receive their long-term enduring character (Remer 2004). The degree of standardization is again composed by its *temporal durability* and its *validity without exceptions* (Remer 2005). Supply chain partners may decide to instruct the relevant governance positions only for the duration of one transaction (e.g. for the delivery of one container), or they might instruct the governance positions in such a way that it is valid for all future transactions (e.g. for the steady supply with apples). Furthermore, they might instruct all governance positions in the same way (i.e. validity without exceptions), or might instruct the purchasing and sales departments to negotiate fiercely with each other, while the outbound and inbound logistics department shall try to find best solutions jointly.

Finally, *formalization* refers to the socio-spatial validity and rigidity of programming of governance positions (Remer 1989). Governance positions in more creative work areas (e.g. joint product development) might receive less formalized instructions, whereas governance positions e.g. in accounting might be more formalized (i.e. low *socio-spatial validity*). Furthermore, deviations from the instructions can be either penalized or tolerated. For example, retailers in European countries nowadays often require their suppliers to implement Efficient Consumer Response (ECR) or Category Management (CR) programmes to increase food quality and to cut costs. Those suppliers not able to comply with these requirements are replaced (i.e. high rigidity) (Fearne & Hughes 2000).

## **Concluding Remarks**

As can be seen, the approach offers a considerable variety of design options and descriptive specifications of elements of organizational structure. According to Ansoff & Brandenburg (1971), the purposeful selection of options of organizational structure in consideration of the organization's strategy, as well as environmental conditions impacting the organization, can be understood as the process of organizational design. Thus, organizational design of supply chains is the realized organizational structure of supply chains, which supply chain participants tried to achieve and which is as similar to the desired structure as the supply chain can get.

Even though the terminological framework by REMER has a broad applicability across organizational designs and even across organizational boundaries, it also bears some disadvantages. Firstly, the measurement of organizational structures is difficult to realize. Especially in social science, the operationalization of research objects represents a challenge, due to the intention to analyse abstract constructs, which cannot be directly observed in reality (Kromrey 2009). This problem has also been acknowledged by Remer (1989), who therefore illustrates some potential indicators of organizational structure. Furthermore, the complexity of combinatorial options might not allow for a complete empirical examination and validation of hypotheses.



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# FRAMING THE FUTURE: SME LOGISTICS SERVICE PROVIDERS AND SCENARIO PLANNING

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## ABSTRACT

In recent years, the transport industry has encountered numerous challenges. It experienced strong growth, but also many uncertainties. In many cases, logistics service providers were forced to change their strategy. So, the question for logistics service providers arises "how to deal best with uncertainties?" We build a hypothesis on the question how SME logistics service providers had been dealing with the uncertainties and developments they had been faces with. In order to test this hypothesis, we questioned 13 SME logistics providers from the Dutch region of Nijmegen on their policies how to cope with the near future. Our initial impression was that they tackled these problems mainly on a day to day basis. That proved not to be true. But our research shows that they are aware of the changing environment and but do not translate this into targets which makes it difficult to be prepared for such occasions. Another finding is that SME logistics service providers want to give scenario planning an important role to determine their strategy.

## INTRODUCTION

"The daily struggle for survival keeps me from looking ahead to see what might happen tomorrow". "As a SME transport company, we are completely depended on whatever happens with our shippers". These are just two quotes from SME logistics service providers participating in a research we conducted amongst the branch in 2011. We had heard these remarks before from SME logistics service providers, so we wanted to find out how they handled coping with their future. During the last decade the industry has seen a huge growth but a sharp decline during the last year. We wanted to understand if and how they prepared for these uncertainties. We especially wanted to find out if they used a systematic approach or just went from case to case and whether they used tools like scenario planning (Schwartz, 1996; Lindgren & Bandhold, 2003).

## RESEARCH METHODOLOGY

As basis for our research we took the Balance Scorecard (BSC), which was developed by Kaplan and Northon (1992) to illustrate the translation of the company's vision into a strategy. BSC is a model based on financial measures for the success of a company, but supplemented with aspects from other perspectives – customer, internal process, and learning, these financial measures link strategic vision with operational activities. This model provides in a framework which we be believe is easily recognized by logistics service providers: create a vision based on your market but with profit as the most important outcome .

Our target group are SME logistics service providers. We took them because they:

1. Most likely do not have the man power to formulate alternative scenarios for the future;
2. Are often family owned; The bond between the owners and senior management is always very strong in these types of companies (Flören & Zwartendijk, 2004). This close bond can have an impact on the way how a company looks at its own future.
3. Could be depending on one or two major customers.

These aspects could have an impact on how SME logistics service providers take a different look on their own future as large logistics service providers. Based on these three aspect we have formulated a hypothesis:

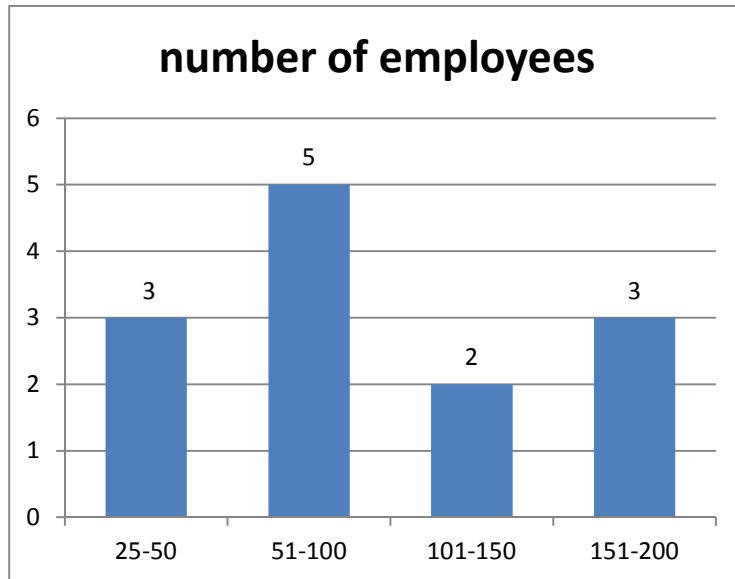
SME logistics service providers do not prepare a strategy for eventual situations in the future.

To test our hypothesis we did a survey under SME logistics service providers in the area Nijmegen-Eindhoven. We set the maximum work force at 200 full time employed (FTE) employees. This number does not include potential hired capacity from third parties. We also set a limit to the minimum number to 25. This will exclude the large group of owner operator truck drivers. We believe that this group will have its own specific problems which should be the subject of a different study. We called 40 companies to ask for their cooperation and we found 13 who wanted to participate to an one hour unstructured interview. Before we conducted this interview we send them an email on what we would like to discuss to help them to be prepared. Table 1 lists the interviewees , the company size, market in which they operate and their respective activities.

<b>Company</b>	<b>FTE</b>	<b>Market</b>	<b>Activities</b>
1	101-150	Exceptional Transportation	National Transport, Warehousing
2	101-150	Physical Distribution	International Distribution, Warehousing, VAL
3*	51-100	Events	Setting Up Sites
4*	151-200	Transport Perishable Foodstuffs	National Distribution, Warehousing, VAL
5	151-200	Transport Perishable Foodstuffs	National Distribution, Warehousing, VAL
6*	25-50	Building Material	Transport, Warehousing
7*	51-100	Theatre/Entertainment	International Transport, Warehousing, VAL
8	151-200	Heavy Goods	International Transport, Warehousing
9*	51-100	Physical Distribution	National Distribution, O Warehousing
10*	51-100	Transport Perishable Foodstuffs	National Distribution, Warehousing, VAS
11	25-50	Courier Transport and Express Services	Courier Transport Services in 25 Km Radius
12*	51-100	Transport Perishable Foodstuffs	National Transport, Warehousing
13*	25-50	Transport Perishable Foodstuffs	National Transport, Warehousing

**Table 3**list of interviewed companies

\* (the numbers 3, 4, 6, 7 , 9, 10, 12 and 13) indicates a family owned company.



**Figure 4 distribution of interviewees and company size**

The interviews were held at the company's location and the interviewee was always (co) responsible for developing the company's strategy. Every interview was recorded, transcribed and send to the interviewee for correction and omissions.

### **INTERVIEW RESULTS**

In the interview we asked the interviewee about their views on:

#### *1. The vision of the company*

Four (1, 4, 9 and 13) of the thirteen companies (31%) have as an objective that they want to grow. For three (2, 6 and 12) respondents (23%) mere survival is at the moment the main objective. For the remaining six (46%) finding a specific niche should secure their business activities. All respondents report that there is a lot of competition in the transport sector and therefore they are also trying to drive at a lowest possible rate service striving for efficiency. Often the term "dog eats dog" is used. The vision of company 6 is their opinion on the whole industry, not a vision for the company itself.

#### *2. Horizon of policy formulation*

It is remarkable that some companies indicate a planning horizon of one year (3,4 and 6) or less than 5 years (1, 2 and 7). The question may be whether strategic planning is a) a moment of reflection on the future or b) a tactical planning. The period of less than five years used by the companies above, would rather point to tactical planning as to strategic planning (Dess et.al, 2010, Thompson et.al., 2010; Horngren et al, 2012, p 206). What is striking is that 54% of companies do not meet at a fixed time to debate the strategy. For this group, policy decisions are an ongoing process which is done alternately with the other activities.

#### *3. Who formulates the strategy*

For 22% (6, 7, 10) of the companies surveyed the strategy is formulated by just one person. In 14% (11, 13) of the cases, this is done by two persons and in remaining 64% the strategy is formulated by the whole management team.

#### *4. Scenario planning (Present use and Future use)*

Of the companies surveyed 12 (92%) are familiar with the aspects of scenario planning. 15% (2, 5) uses scenario planning at present. These companies have invented different scenarios and worked these out to be prepared for the unexpected. Of the 11 companies that do not use scenario planning, the current economic crisis

has surprised 5 (6,8,10,11,12). Company 13 suddenly discovered it was extremely depending on one major customer. They indicated that they might have seen this earlier if they had used scenario planning. Of the 11 (85%) companies that do not use scenario planning, eight (62%) companies (1, 3, 4, 8, 9, 10, 11, and 13) are considering using scenario planning in the near future. The main reason given is to map the growth potential of the company. The remaining 38% that do not plan to adopt scenario planning (6, 7, 11) indicated that they like the way how they are working at the moment and want to change nothing.

*5. information sources*

All companies surveyed are members of branch associations. Six companies (2, 5, 10, 12, 13, 14) regularly attend meetings of these associations to discuss various logistical issues. The eight other companies keep themselves informed through magazines.

*6. Dependence on customers*

Respondents 2 and 5 (15%) did not want to answer this question as they considered this information competition sensitive. Of the remaining 11 respondents, five (1,6,7,11,13) (45%) mentioned dependency on one major customer and four respondents (3,9,10,12) 36% mention large accounts but do not see this as a potential problem. Only two respondents (4, 8) (18%) indicated a broad customer base and saw no danger if any customer was to disappear.

*7. Greatest uncertainties in future*

When asked to name one specific uncertainty which would have a huge impact on the company the respondents gave the following answers as found in table 2:

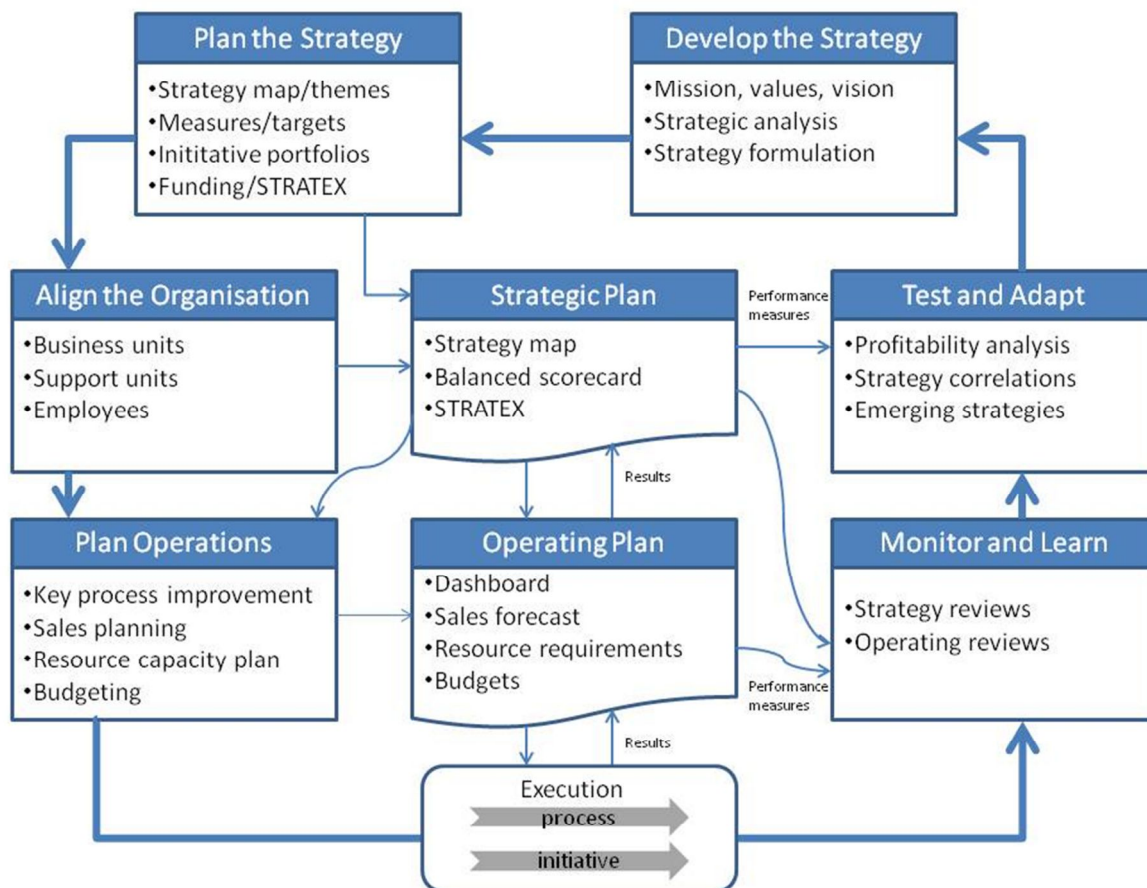
<b>Greatest Uncertainty In The Near Future</b>	<b>Company</b>
Loss of a Major Customer	1, 2, 3
Crises, Economic Development	6, 8, 9
Obtaining of Personnel/Staffing Problems	5, 12
Having Just One Policymaker	7, 10
Fuel Prices	13
Company Growth	4

**Table 4 main uncertainties**

Only company 11 (8%) saw no uncertainties for the near future and expects to continue as usual.

**ANALYSIS**

The information obtained from the interviews was labeled and placed in the management system as developed by Kaplan and Norton (2008) as shown below in figure 2.



**Figure 5 The management system: linking strategy to operations**

If we fill the found labels in this ABC model we get the following view as found in table 3:

Aspect of Kaplan and Norton	Remarks
<ul style="list-style-type: none"> <li>Develop the Strategy</li> </ul>	All respondents do have a mission and vision on what they want to do and what they aspect will happen in the future. However distant (or better close) this future may be. But these are sometimes wishful thinking (growth) or just survival.
<ul style="list-style-type: none"> <li>Plan the Strategy</li> </ul>	Strategies are seldom written down! Also no one mentioned any measures or targets which should be met. This makes these plans difficult to serve as a focus point. They often change as the horizon is short and are perhaps more tactical or even operational plans instead of strategic plans.
<ul style="list-style-type: none"> <li>Align the Organisation</li> </ul>	Most respondents mention that their main flexibility is to be found in their employees. They have taken on more staff with temporary contracts or with flexible working hours. No real changes were mentioned for business units and support units.
<ul style="list-style-type: none"> <li>Plan Operations</li> </ul>	Not one respondent mentioned anything which could be placed under the labels "key process improvement", "sales planning" or "budgeting". If anything is mentioned, it is planning the availability of (human) capital.

<ul style="list-style-type: none"> <li>• Monitor and Learn</li> </ul>	With nothing set as targets for strategy and no measures mentioned, it is not surprising to find nothing on monitoring and learning on a strategic level. With so many respondents mentioning "survival" perhaps learning on a strategic level is a luxury at the present few can afford in this business.
<ul style="list-style-type: none"> <li>• Test and Adapt</li> </ul>	Again nothing set as a target, so how to test and eventually adapt?
<ul style="list-style-type: none"> <li>• Strategic Plan</li> </ul>	With so much handled on a day-to-day basis approach, a strategic plan might just be what this group is needed. But at present nothing was found which could be placed here
<ul style="list-style-type: none"> <li>• Operating Plan</li> </ul>	No dashboard for strategy is mentioned by anyone. All respondents focus on day-to-day problems and solve these as they come.

**Table 5 ABC and the findings**

### CONCLUSION

Our sample is not meant to be representative, nor to draw any definite conclusions. But we still can say something in regards to our hypothesis. Based on our findings, SME logistics service providers seem not to link the future with present day handling. They seem more concerned with the ad hoc situations as with something which might perhaps occur. But they seem aware that the future is something which they should be prepared for, but are not 100% sure how this should be done. As all participants were a member of branch organizations, we would suggest that the latter could play an important role in this process to help SME logistics service providers to define future problems and possibilities. These branch organizations have the manpower missed by the SME logistics service providers and could provide their members with a wider knowledge and insight into the whole market. Still we want to suggest to SME logistics service providers to use scenario planning tools in order to draw the outlines of what could happen and where potential opportunities lie.

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# THE ROLE OF REGIONAL CLUSTERS IN SUPPLY CHAINS: AN OVERVIEW OF THE LITERATURE

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## **Introduction**

To join several companies into a cluster may be beneficial for many reasons. In the first place it makes it possible to increase the competitiveness of participating companies thanks to the relative increase of market power, or increased supply of information. Further through the cluster companies may reach higher incomes or cost savings due to the possibility of sharing particular business activities (shared funding of research and development, shared marketing and promoting activities, joint access to information, joint purchases from suppliers, better negotiating power, etc.). The "cluster" brings advantages not only to its members, but, in general, it also stimulates an economic growth, the increase of competitiveness and efficiency in the given branch, stimulation of innovations, support of establishing new subjects, increase of export, etc. (Skokan, 2002, Puppim, 2008). That is the reason the author of this article wants to focus on description how supply chain relationships work in the frame of the cluster.

## **Review of literature**

The following review of previous literature intent to provide a chronological ordering of research topics and to identify important areas that have contributed to knowledge base. The British economist Alfred Marshall started to research the territorial concentration of industrial branches in his book the Principles of Economics already in 1890. Besides others, he stated that industrial branches were frequently concentrated locally and they acquired considerable contributions from externalities, such as savings from the scope and "spilling over" the knowledge arising from these concentrations. Among the principal reasons for the origin of so-called industrial districts Marshall indicates natural conditions, such as the character of climate and land, existence of mineral resources and easy access to land and water (Marshall, 1947).

However the greatest degree of acknowledgement in the sphere of competitiveness of cluster has been reached due to the work of Michael Porter. During the last decade Porter's idea of „clusters“ made a significant effect on the study of regional and local „concentration“ (agglomeration) of branch specializations, innovations and companies. Michael Porter introduced his cluster model for the first time in the book The Competitive Advantage of Nations in 1990. Porter and his team have engaged in a comprehensive regional mapping project covering many U.S. regions in order to identify promising regional traded clusters. Michael Porter maintains that cluster initiatives should be designed to support microeconomic (firm-level) development in regions. Fostering a high productivity, innovative-driven environment for local firms should be the chief purpose of regional policy (Porter, 1990,1998).

Michael Porter argued that the strength of a cluster depends on several interacting factors, which can be grouped under four headings (see chart 1):

1. firm strategy, structure and rivalry,
2. demand conditions,
3. related and supporting industries,
4. factor conditions.

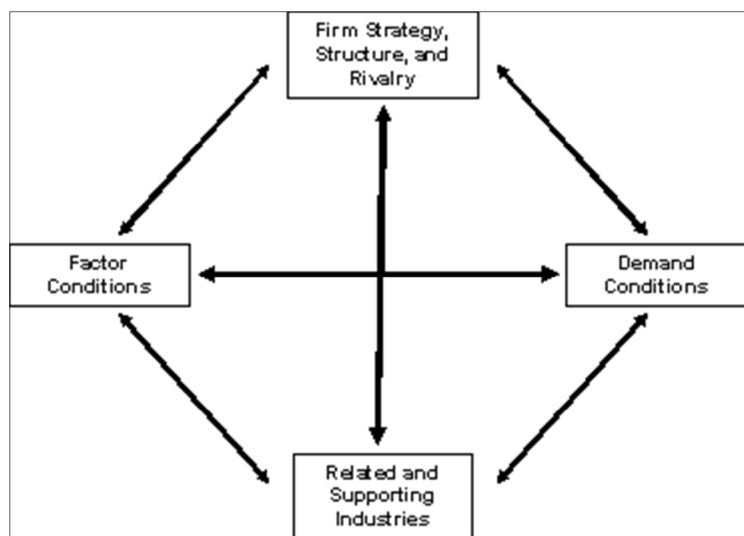


Figure 1: Michael E. Porter's Diamond Model

An example of this model can be seen in the electronics cluster in Austin, Texas. (Anderson, 2004). There are some 400 companies and the large concentration of software and semiconductors. Demand conditions are represented by a strong local base of technologically sophisticated buyers. In general fast going venture capital network, strong research base and upstream suppliers are part of related and supporting industries. Factor conditions are represented by above average education system, low taxes, low unionisation, low cost of living and a high quality of life (Noordewier, 1990, Daugherty, 2011).

Despite the interest from the side of economic geographers, economists and managers in the industrial localization in last two decades, clusters in the sense of territorial concentration of mutually interconnected companies, suppliers and other related organizations have existed here for centuries (Sölvell, 2003). The „success“ of very famous branch districts or clusters, such as already mentioned Austin, Texas, but also Silicon Valley, Route 128 or Research Triangle (all in the USA), have also contributed to it.

In the course of twentieth century a number of other authors dealt with the relationship of the concentration in the industry (or innovations) and the economic performance (for example, Weber, 1909; Christaller, 1933; Lösch, 1940; Harris, 1954; Schumpeter, 1942; Hayek, 1945; Nordhaus, 1962; Olson, 1965; Williamson, 1985). Randomly we can name the works of authors, renowned researchers, in the area of the systems of innovations and regional development, such as Asheim, Bergman, Lundvall, Schmitz, Cooke and others (Skokan 2007).

Presently several academic workplaces in the Czech Republic deal with the task of clusters (Skokan 2002, Mikoláš 2005; Malinovský 2005). A significant influence on spreading the knowledge about clusters, especially, among the academic staff, played the publication of the monograph *Competitiveness, Innovations and Clusters in the Regional Development* (Skokan 2004). Other workplaces studying intensively the task of clusters for already several years are the university departments in Pilsen (Leeder 2004; Šimon 2006; Lodl 2006; Sysel 2006). For already several years the Department of Business Administration at Faculty of Economics at Technical University of Liberec has been dealing theoretically, as well as practically with the development of clusters, especially, in the area of small and medium-size companies (Jáč 2005; Rydvalová 2005; Žižka 2006), as well as the workplace in Zlín (Pavelková, Jirčíková, 2008, 2009).

### **Classification of clusters**

The Czech Investment and Business Development Agency distinguish from two types of clusters. The value chain cluster and clusters based on knowledge. The purpose of this paper is to explore the role of regional technological and industrial clusters and its obstacles from the perspective of supply chain management. From this point of view it is important to identify the difference between the value chain cluster and supply chain cluster. The first one mentioned is based on the assumption that the objective of business is to create a value for the user of the given product or service. On the other hand, the supply chain cluster is a network of facilities that provide for the function of material supply, transformation of these materials into final products and their transportation to the customer, the chain complexity depends on the branch or type of company (Thorburn, 2002).

### **A Supply Chain Perspective of Cluster Manufacturing**

The partial task of this article is to define the logistics in the cluster as the core support and the mediator of close cooperation between companies and in the supplier-customer relationships and their functions in the context of the management of innovations in companies. The cluster structure is usually formed by three subjects (Gattorna, 2009). The core of cluster is the companies that are its principal participants. Further there are supporting companies, mainly suppliers of specialized machinery, components, raw materials and the sub-suppliers that may be assigned with particular tasks from the side of manufacturers. The soft supporting infrastructure is linked to these two layers. Above all, it is the commitment of the whole community, i.e. university, local business and professional association, agency for the economic development and other institutions supporting their activities. The quality of soft infrastructure and the scope of team work involved in it are very important factors for the development of any cluster. The last layer is the hard supporting infrastructure; road communications, ports, waste management, communication links, etc. The quality of this infrastructure must reach at minimum the same quality as in the competitive clusters, either local or more distant (DeWitt, 2006).

According to Sheffi (2012) attributes of successful logistics clusters are favorable geography, supporting infrastructure, supportive and efficient government, education, research and innovation, collaboration and value-added service. Logistics clusters are geographically cohesive, so they naturally include people with similar backgrounds and cultures. This enables better collaboration among organizations leading to better working partnerships and lower transactions costs. Logistics clusters enable physical interactions that leads to tacit knowledge exchange. Industries in a cluster have common needs that concerns lobbying and cluster development activities on one hand, but also investments in research and development and collaboration with universities on the other hand. Concerning supply base, logistics clusters attract suppliers that co-locate next to their largest demand centers. This is economically efficient for both the companies located in a cluster and the suppliers (Barkley, 2007).

In order to identify organizational and managerial solutions for improving co-ordination logistics integration areas can be analysed. Regarding the different points of view, e.g. this could be done within each business (internal integration), between businesses located at different stages of the channel (vertical integration) or between different businesses located on the same level of the channel (horizontal) (Batenburg, 2003). Certainly the cluster also shares the logistics management, either organized internally, or in the form of outsourcing or 3PL providers. According to Harrigan (2003) vertical integration is a two-edged sword that must be employed with dexterity if so to improve productivity.

### **Business Intelligence in Cluster**

The guideline of all trends that concern the area of logistics and clusters consists in the capability to evaluate a piece of quality information from the data by means of knowledge and experience in respect of artificial intelligence (Fiala, 2009). Primarily it is possible to find such sources that are the most available and cheapest, i.e. the internal sources of the company. For this purpose we use CRM (Customer Relationship Management) that comprises all processes and activities related to the customer, his preferences, needs, relations, etc. On the next layer the data are necessary to be transformed into the form which is acceptable for entering into the Business Intelligence. For this there are determined the applications of ETL (Extraction, Transformation, Loading), so-called data pumps that extract, process and also save the data, or the application of EAI (Enterprise Application Integration) that integrates the primary systems of the company. Further these data enter into the database components – into the data warehouse, data market, operational data store, or into the temporary data storage (Data Staging Area). Then the integrated and structured data should be transformed to the information. Therefore, in the next layer there are used analytical components, for example, reporting, OLAP (On Line Analytical Processing), or Data Mining (Fiala, 2009). The theme „Internet of Things“ is topical, not so far known (for the general public), but almost revolutionary in both the logistics and economics, but also for our everyday lives. The Internet of Things utilizes, combines and develops modern technologies, such as EPC (Electronic Product Code), RFID (Radio Frequency Identification Device), ITS (Intelligent Transport System), GPS (Global Positioning System), and consequently also the application of M2M (Machine to Machine). Generally it is a network where the objects and even persons may automatically communicate with the computer and also between themselves. Due to such a network all logistic activities in cluster could be identified, administered and also stock taken by the IT systems.

### **Methodology of Analysis and Mapping of Clusters in the Czech Republic**

The purpose of cluster mapping is to determine the sources of existing and potential advantages that could further and faster develop the combination of governmental and private sources in order to reach common objectives (OECD, 2001).

According to Skokan´s (2003) methodology of analysis of clusters, six basic steps should be followed:

- 1) To define the environment for the successful state support.
- 2) To identify economically advantageous localities for business subjects (including investors from abroad).
- 3) To create environment for innovative projects.
- 4) To evaluate risks by identifying branch clusters.
- 5) To identify branches with existing or potential source of export.
- 6) To identify internal regional ties increasing the competitive advantage and being the basis for the cluster innovation.

The process of mapping should be concentrated on:

- Identification of existing and potential clusters in the regions or cities of the Czech Republic.
- Identification of key problems and advantages for the groups of companies, universities and research institutes supporting the development of innovations and increase of competitiveness.
- Processing action plans for stakeholder groups with the objective to solve common problems and opportunities with the assistance of governmental subsidy. (Žižka, 2006).

The maps of clusters are the tool for tracing and presenting relationships of the supply or value chain in the cluster some of which are stronger than the other. Mapping may also

be an effective support in acquiring new regional investments or in supporting the cluster in export markets (Pavelková, 2009).

### **Tools for Identification of Potential Clusters**

There are three basic tools for identification of potential clusters according to Žižka (2006) following.

1. Identification of business relations between different industrial branches in the frame of the given economy by means of input-output analysis. Is used for the presentation of supplier-customer relationships inside the cluster and between clusters.
2. Calculation of coefficient of localization (critical factor is employment rate in the sector in the region or employment rate in the sector in the whole country).
3. Detection of comparative advantage – regional export share of each sector towards the export of manufacturing sectors and in comparison with the average in the countries being compared.

After the implementation of analysis and deeper understanding the dynamics of the supply chain of the given industry, and discussions with companies it is possible to represent clusters by the form of map.

In general the purpose of the map of the cluster is to identify and demonstrate significant supplier-customer relationships between branches in the cluster, gaps in the cluster in which there is a potential for the entry of domestic or foreign investments and the opportunity for strengthening the ties and added value on the basis of a greater cooperation. Further maps are used for expressing the cluster capacity for the export markets; according to these maps it is possible to determine weak and strong points in terms of inputs or outputs of the cluster.

### **Development of Cluster Initiatives in the Czech Republic in Period 2003 – 2013**

Based on the research made by the team from Technical University of Ostrava and the CzechInvest agency, the development of cluster initiatives in the Czech Republic started to be mapped in 2003. In the period 2003 – 2004 there was rather the organizing of seminars and workshops in order to involve particular participators in the preparation of proposals for potential clusters in particular regions. This kind of business was supported from the Operational Programme Industry and Business – Clusters, and already since 2005 the businessmen have shown their interest (for example, from Pardubice, Zlín, Liberec, Ústí nad Labem, Karlovy Vary) in the formation of specific cluster initiatives. (Skokan, 2007).

As an example of the Region of Liberec, since 2005 you can see the development in the formation of cluster initiatives, above all, in these, for this region, typical branches: textile industry, glass industry, the manufacture of glass beads and fashion jewellery (see figure 2) In this region the support of clusters has long been apparent not only from the side of the state local government, a significant element influencing the formation and development of cluster initiatives is the traditional and extensive network of professional secondary schools and vocational training centres with the university providing the education in the given professions in this region. After 2010 the list of existing cluster initiatives has been completed with the association of cluster type dealing in the research of nanotechnologies.

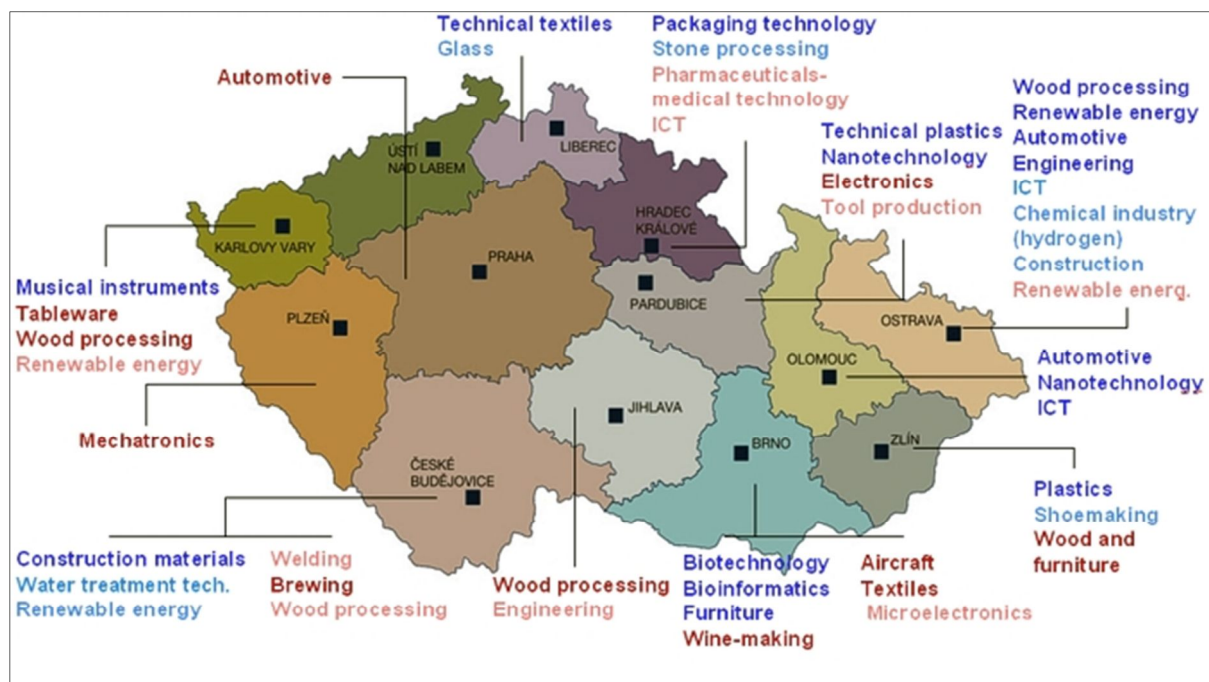


Figure 2: Map of Cluster Initiative in Czech Republic  
 Resource: Available at <http://www.czechinvest.org/oppp-klastry>.

In 2013 there were identified following four cluster initiatives in the Region of Liberec: glass industry, textile industry, manufacture of fashion glass jewellery and treatment of waste for further utilization. In addition currently there are three natural clusters also existing in the Czech Republic (according to the definition of M. Porter, so called "natural" clusters, without any legal form). There are brewery cluster, glass cluster and automotive cluster.

### Conclusion

According to this literature overview, the logistics and supply chain management represents one of the tools for increasing the competitiveness of companies within the cluster. It enables the participating companies to reach a higher efficiency and help them to increase also the productivity through a better access to specialized suppliers, technologies and information, as well as reach a higher innovative potential of cooperating companies due to pouring the knowledge inside the cluster or generating new ideas and a higher pressure to innovate.

Clusters can share following areas of activities, i.e. networking (formal and informal flow of information), management of human resources (organization of education, training, seminars and conferences), research and development (new products, innovations, optimizations, cooperation with research institutions), commercial collaboration, marketing a public relationships (common marketing researches, participation in fairs, etc.), investments and, last but not least, also lobbying. Reasons of cluster creation may be several, among them, for example, own initiative, government support, support of regional agencies, or support of university representatives.

The purpose of this paper was to explore the role of regional technological and industrial clusters and its obstacles from the perspective of supply chain management. Author will focus on implementation of the pilot surveys in the field of logistics clusters and vertical integration in the Czech Republic in her future research activities.

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# DRIVERS AND BARRIERS OF ISO 26000 IMPLEMENTATION: THE CASE OF INDIAN AUTOMOTIVE FIRMS

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## ABSTRACT

**Purpose:** The aim of this study is to determine and prioritise the drivers and barriers of ISO 26000 implementation in Indian automotive companies.

**Design/methodology/approach:** Based on extensive literature review regarding global standards including ISO 9001, ISO 14001 major drivers and barriers of ISO 26000 implementations are identified. Data is collected from senior managers of four large Indian automotive companies. The analytical hierarchy process (AHP), a multi-criteria decision making method, was used to analyse data and prioritize the identified factors.

**Findings:** Results indicate that stakeholder engagement, and seeking legitimacy in the social responsibility (SR) policies are the two most important drivers of ISO 26000 implementation. Factors such as implementation costs is regarded as critical barrier followed by integration issues, financial crisis, lack of awareness of standard and obtaining management support. Resistance to change is the least critical barrier for implementation.

**Originality/Value:** The findings of the study can act as a reference guide to managers and senior executives developing strategies to overcome ISO 26000 implementation challenges.

**Keywords:** ISO, ISO 26000, corporate social responsibility, social responsibility, supply chains, India, automotive

## 1.0 INTRODUCTION

Corporate social responsibility (CSR) defined as how firms integrate social and environment sustainable concerns in their business activities, is not a new concept. However, until recently its practices in the context of supply chains remained limited. In the context of globalised supply chains, issues such as child labour, working conditions and women discrimination became more prominent in developing countries (Arevalo & Aravind 2011). In order to avoid the risks associated with these issues, ISO (International Standard Organisation) took initiative in developing a standard on CSR called ISO 26000. Irrespective of organisations location, size, type, structure and ownership, ISO 26000 can be used to implement SR activities.

CSR came a long way from being merely charity donations towards SR activities that are integrated into corporate structure (Arevalo & Aravind 2011). This paper aims to identify and prioritise drivers and barriers of implementation of ISO 26000 standard in the context of Indian automotive firms. The rest of the paper is organised as follows. Section 2 presents a brief discussion on SR and ISO 26000 standard. This is followed by a review of literature on drivers and barriers of ISO 26000 implementation in section 3. Section 4 provides research methodology and background of the sample organisations and respondents. Analyses, results and discussion are presented in section 5. Finally, conclusions are drawn in section 6.

## 2.0 SOCIAL RESPONSIBILITY AND ISO 26000

CSR is a notion with many meanings often confused by different interpretations (Castka & Balzarova 2007; Dahlsrud, 2008). The term SR is used instead of CSR in context of

ISO 26000, as it is intended to be used by any type of organisation rather than focusing only on large corporations. According to ISO 26000 SR is defined as the “organisations responsibility for the impacts of its decisions and activities on society and environment that contributes to the sustainable development by taking into account the expectations of stakeholders” (ISO 26000, 2012). It also states that responsibility should be integrated throughout the organisation and practiced in its relationships while in compliance with legislation through transparent and ethical behaviour (ISO 26000, 2012).

The field of SR is a ‘multi-stakeholder and multi-disciplinary area of inquiry’ (Castka & Balzarova 2007, p.276). Although SR is well established concept, it is dynamic and evolving continually (Moratis & Cochius 2011). ISO 26000 standard consists of seven clauses (see Table 1) and it aims to provide guidance on how organisations should develop their unique SR profiles.

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### **Introduction**

- 1. Scope-** Guidance on CSR to all types of organisations, regardless of size or location
  - 2. Terms and definitions-** Definitions of key terms used in the guideline
  - 3. Understanding social responsibility-** An elaboration of history and characteristics; relationship between social responsibility and sustainable development is interpreted.
  - 4. Principles of social responsibility-**
    - Accountability
    - Transparency
    - Ethical behaviour
    - Respect for stakeholder interests
    - Respect for the rule of law
    - Respect for the international norms of behaviour
    - Respect for the human rights, are the principles that the SR is based
  - 5. Recognizing social responsibility and engaging stakeholders-** The two are the fundamental practices of social responsibility, that needs to be related and how to identify the role of organisations sphere of influence is discussed.
  - 6. Guidance on social responsibility core subjects-** Selection of core subjects that suits to the organisation profile and implementing them is explained, core subjects identified by the standard are:
    - Organisational governance
    - Human rights
    - Labour practices
    - The environment
    - Fair operating practices
    - Consumer issues
    - Community involvement and development
  - 7. Guidance on integrating social responsibility throughout an organization**
- 

Table 1: ISO 26000 structure and clauses (Source: Adapted from ISO 26000, 2013)

## **3.0 LITERATURE REVIEW**

Drawing from extensive literature on ISO standards implementation and SR practices, we identified nine determinants that affect the implementation of ISO 26000 of which three are considered drivers and six are barriers. These determinants are discussed as follows:

### **3.1 Drivers**

#### **3.1.1 Stakeholder engagement**

Engagement with stakeholders helps to identify the interests of stakeholders in business process. Stakeholder engagement differentiates sustainable business operations from usual business practices (Pojasek, 2011). In social and environmental standards,

engagement with stakeholders helps in consensus building and sharing of knowledge (Balzarova & Castka, 2012). Stakeholder engagement helps to eliminate greenwashing-over emphasising the sustainability aspects of a product and it promotes to build trust among business partners. Arevalo and Aravind (2011) stated that implementing CSR activities helps in improving relationship with stakeholders.

### **3.1.2 Adoption of strategic partnerships**

Strategic partnerships and collaborations are important elements of global supply chains. Perera (2008) stated that ISO 26000 will be implemented in companies who are a part of large supply chains or for those looking to build strategic partnerships. Implementing ISO 26000 helps to build relationships with companies, government, suppliers, customers and community in which they operate (ISO Focus+ 2011). Though ISO26000 can not be used as a code for supplier selection, it builds credibility and trust among the partners as they share sensitive information (Castka & Balzarova, 2008).

### **3.1.3 Seeking legitimacy of internal policies**

In supply chains, large organisations develop their own internal policies and enforce them on the other partners to reduce the complexity (Castka & Balzarova 2008). In organisational context legitimacy is related to actions that are desirable and proper within socially defined norms and beliefs. Often the name ISO is interpreted as benchmarks for good practice. Implementing standards helps to seek legitimacy from surroundings and symbolises the responsible actions of organisations with respect to social and environmental aspects and may also act as an effective tool for change (Schwartz & Tiling, 2009). Implementing ISO 26000 standards satisfies organisation quest for legitimacy of social responsible practices (Castka & Balzarova, 2008; Perera, 2008).

## **3.2 Barriers**

### **3.2.1 Implementation costs**

Costs of implementing environmental, management and social aspects in businesses are high (Arevalo & Aravind, 2011). Costs involved with training, documentation and setup modification are some of the major cost categories for implementing ISO 9000 (Crowe & Noble, 1998). Implementation of ISO 14000 standard also associates with the implementation and maintenance costs (Strachan, Sinclair & Lal 2003; Cassells, Lewis & Findlater 2012). Moratis and Cochiu (2011) listed costs as a major concern of the organisations for implementing CSR practices. Roberts (2010) argued that the costs involved with the implementation of social activity itself contradict the fundamental reason of profit maximization of businesses. Lack of resources is also identified as a major obstacle in CSR implementation (Arevalo & Aravind 2011). There is a cost associated with acquiring expertise and resources to understand and identify the organisations SR profile (Perera 2008).

### **3.2.2 Financial crisis**

An unethical business practice and lack of proper regulation in lending practices is considered as the major source of current financial crisis, which led to the bankruptcy of most successful companies such as Lehman brothers (Roberts 2010). As a result of this scenario organisations behaviours towards CSR are categorised into two extremes. On one extreme organisations are investing in SR activities to increase credibility and legitimacy which no longer exists. On the other hand, businesses are only concentrating and investing on the activities that result in economic returns. Arevalo and Aravind (2011) discusses that current financial crisis is considered as the factor that made firms harder to allocate resources for CSR initiatives. Current global financial crisis is still affecting businesses and their supply chains making it unfavourable conditions for the implementation of ISO 26000.

### **3.2.3 Lack of awareness of standard**

Lack of knowledge on CSR practices and difficulty in understanding the standards is a major obstacle in CSR implementation (Arevalo & Aravind 2011). There are several misunderstandings and myths such as; ISO 26000 is a management system for

certification, which causes ambiguity and resistance to the implementation (Moratis & Cochiuș 2011). Having a clear strategy and understanding leads to the success of implementation of a standard (Cassells, Lewis & Findlater, 2012). This was also highlighted at the Geneva conference on road map to ISO 26000 (Cahill 2012).

### 3.2.4 Obtaining buy-in from management and staff

Commitment from top management is most crucial factor for successful implementation of any new initiative. In some cultural contexts middle level managers are more favourable in driving the change and applying new standards (Setthasakko 2009). Arevalo & Aravind (2011) and Moratis & Cochiuș (2011) also supported that lack of support from middle and top-level management is a major barrier in implementing CSR activities. Relevant literature suggested that the interests in SR activities are limited as benefits of SR implementation are long term and management positions are generally held for short term

### 3.2.5 Resistance to change

Setthasakko (2009) stated that it is not an easy to change the culture, as it includes beliefs, values and ways of thinking of staff members and it requires commitment from employees. Resistance to change to new management systems is the most common barrier found in implementing ISO standards (Moratis & Cochiuș, 2011; Cassells, Lewis & Findlater 2012). Pojasek (2011) emphasised that since integration of core aspects of SR is a stage in the implementation of ISO 26000, it demands organisational change.

### 3.2.6 Issues of integration with existing system

Until recently, there was no consensus on CSR practices and hence, it include topics ranging from corporate philanthropy to environmental aspects. Since CSR is a broad concept, most organisations may already have SR strategy in place that need to be integrated with the new system. The primary objective of ISO 26000 standards is to become all-encompassing guidelines to implement ISO 26000 (Moratis & Cochiuș 2011). Organisations need to take into consideration that the standards are not intended to replace the existing CSR system, instead it should complement it (ISO focus+ 2011).

Based on the concepts discussed in section 3, we proposed a conceptual model that can be used in this study and can be seen in the Figure 1.

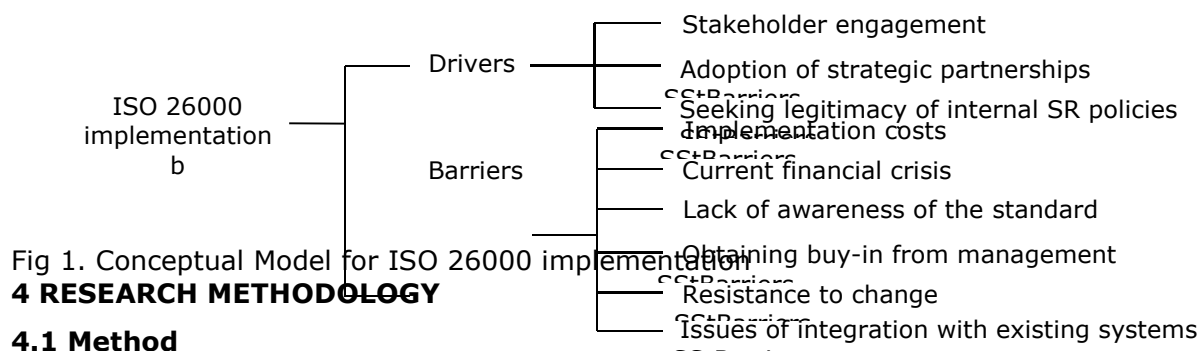


Fig 1. Conceptual Model for ISO 26000 implementation

## 4 RESEARCH METHODOLOGY

### 4.1 Method

Multi-criteria decision making analysis (MCDM) is a mathematical tool used for evaluating multiple conflicting criteria during decision making process. Analytical hierarchy process (AHP) is a MCDM tool for decision making process which integrates qualitative and quantitative information simultaneously for ranking alternatives. AHP has been widely used in multi-attribute analysis and decision problems in areas such as supplier risk assessment (Wang et al. 2012), supplier selection (Xu et al. 2013) and also prioritising factors during implementation of ISO standards (Crowe & Noble 1998). It helps to structure a complex problem into simple hierarchy and also to provide best choice by rating among the alternatives. The modelling process of AHP in this study involves four steps:

**Step 1: Identification of key factors.** Assessment of the critical factors of ISO 26000 implementation in Indian automotive manufacturing firms identified nine factors (see Figure 1) of which three are drivers and six are barriers.

**Step 2: Structuring problem as a hierarchy.** The structuring step consists of breaking down any complex multi-criteria decision-making problem into a series of hierarchy.

**Step 3: Application of prioritisation procedure and collection of respondents' opinion.** Application of prioritisation procedure determines the relative importance of the criteria in each level, by comparing criteria pair-wise in terms of their importance to the criteria in the next higher level. The scale used for pair-wise comparisons in AHP is called a one-to-nine scale. In the process of comparison, square matrices are generated. For a set of  $n$  criteria in a matrix,  $(n^2-n)/2$  judgements are needed as there are 1's in diagonal (comparing criteria with themselves) and the remaining judgements are reciprocals. Based on this process, respondents' opinion is gathered and framed into matrices.

**Step 4: Determination and synthesis of normalised weights.** The normalised weights can be determined by using either eigenvector method or simple row average method. For a further mathematical discussion of this method, see Saaty and Vargas (1982). The overall weights of the decision alternatives are determined by aggregating the weights throughout the hierarchy and the best alternative can be chosen for the decision purpose.

#### 4.2 Sample Selection

The uptake of the ISO 26000 in developing countries is uncertain. Indian government representatives perceive this standard as a barrier for trade and exports, as the standard demands high performance from the companies (Henriques, 2012). However, there are some industries with global supply chains such as automotive which always seeks to adopt standards. To investigate the criticality of the determinants affecting the adoption of ISO 26000 a study within Indian automotive companies was conducted in early 2013. Sample companies and respondents for interviews were selected based upon the following guidelines:

- Large automotive manufacturing companies with some ISO standards in place and existing CSR practices, who intent to implement ISO 26000, and
- Respondents who have experience in implementation of standards and have some exposure with CSR activities.

Four manufacturing firms were chosen for this study. For confidentiality reason, these companies are identified as Company A, Company B, Company C and company D. Two part questionnaire was employed for data collection. Part A contained questions (in AHP format) designed to capture respondents opinions on relative importance of determinants, whereas, part B contained general questions about the company and respondents background. All four senior managers were interviewed over phone for approximately 30 minutes. A summary of these companies and managers position and experience is given in Table 2. All the managers have working experience with ISO standards, CSR practices and familiar with GRI reporting guide lines, so they were in a position to make the judgements on the determinants affecting the implementation of ISO 26000 standards. Responses of interviewees were recorded using AHP matrix, and they were assured that the answers will be kept confidential. However, respondents were not familiar with the AHP data collection procedure. So the following two steps are considered to ascertain the accuracy of data. These are:

1. Respondents were explained the meaning of the integer scores of the 1-9 scale.
2. Respondents were explained how these scores need to be considered while making the pairwise comparisons between any determinants.

Firm	Head quarter	Major Products	Standards and CSR reporting	Position	Qualification	experience
A	India	Automobiles,	ISO 9000	Supply	Master	7

		commercial vehicles and engines	ISO 14001 GRI	chain manager	degree	
<b>B</b>	South Korea	Automobiles, commercial vehicles and spare parts	ISO 9000 ISO 14001 GRI	Production manager	Bachelor degree	5
<b>C</b>	USA	Agriculture, commercial equipment, diesel engines	ISO 9000 ISO 14001 GRI	Supply chain manager	Master degree	7.5
<b>D</b>	India	SUVs, commercial vehicles and tractors	ISO 9000 ISO 14001 GRI	Operations manager	Master degree	5

Table2. Characteristics of the responding firms and respondents

### 5.0 ANALYSIS, RESULTS AND DISCUSSION

In order to determine the priority weight of each determinant, judgement matrices, based on managers' interviews, were translated into the largest eigenvalue problems, and then calculated the normalized and unique priority vectors of weights by using the Expert Choice® software. The overall inconsistency index of judgements was then calculated. This was done taking all responses together using geometric means of participants. Hence, the outcome would identify the degree of importance for each factor as a percentage of total importance of drivers and barriers of ISO 26000 standard implementation.

Priorities with respect to:  
Goal: Critical drivers



Fig 2. Weight priorities of drivers for ISO 26000 Implementation

Priorities with respect to:  
Goal: Ranking CSR implementation barriers

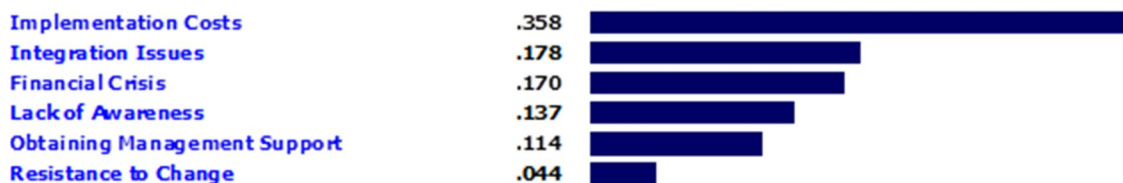


Fig 3. Weight priorities of barriers for ISO 26000 Implementation

The results for drivers and barriers are shown in Figure 2 and Figure 3 respectively. Stakeholder engagement is regarded as the most important driver with an overall weight=0.503. Since the respondents believe that by implementing the standard they can be more engaged with stakeholders and can build common understanding on SR and it also helps to provide legitimacy in their practices, so the second priority as a driver is given to seeking legitimacy of the practices (weight= 0.364). Managers believe that in the case of ISO 26000 standards which cannot be certified, there is no perceived benefits of forming partnerships in supply chains. So forming strategic partnerships is the least priority (weight = 0.133).

Figure 3 displays the barriers of ISO 26000 implementation in Indian firms. Results indicate that the most critical barrier is the cost of implementation (weight=0.358). It is not unusual, as the implementation of a standard requires expertise which is associated with huge costs when the expertise is so limited. The next two critical determinants are integration issues and financial crisis with weights = 0.178 and 0.170 respectively. Currently, all four surveyed firms are using GRI reporting system to report their SR practices. So the respondents feel that the integration with existing practices is a challenge which is the second major concern. Financial crisis is the third major factor. This result doesn't come as a surprise given the fact that the new investment is limited in the current economic environment and managers cannot see the benefits in short run. The least important determinants is the resistance to change with a weight = 0.044.

## 6.0 CONCLUSIONS

In recent years, SR in supply chains has emerged as a major concern for organisations. ISO 26000 is the first international guidance standard on SR which was launched in 2010. Since then there is a wide acceptance of the standards within the business community. This study contributes to the existing literature in the area of ISO 26000 implementation or diffusion. It specifically addresses the drivers and barriers of implementation in Indian firms. Through an extensive literature review regarding global standards and sustainability this research identified three drivers and six barriers of ISO 26000 implementations. Results show that stakeholder engagement, and seeking legitimacy in the social responsibility policies are the two most critical drivers of ISO 26000 implementation. Factors such as implementation costs is regarded as critical barrier followed by integration issues, financial crisis, lack of awareness of standard and obtaining management support. Resistance to change is the least critical barrier for implementation. The results of this study can act as a reference guide to managers and senior executives developing strategies to overcome ISO 26000 implementation challenges.

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# **A LEARNING AND INVESTMENT MODEL FOR QUALITY IN A TWO LEVEL SUPPLY CHAIN**

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The literature on supply chains is full of analytical models that have addressed a number of practical circumstances. Most of these models have studied coordination among the stakeholders by either avoiding or fixing the measure of quality. Although the notion of investment to improve quality, is not new (Ganeshan *et al.* 2001), there is a lot to be studied in this field of research. Recently, this issue has gained more attention in the supply chain literature (Yoo *et al.* 2012 *a, b*). Quality in a product may also improve by virtue of learning (Jaber *et al.* 2008). This article is the first one, to our knowledge, to study the trade-off between learning and investment in quality, in a buyer-vendor supply chain. Learning in quality implies the very fact that the fraction of defectives from a supplier tends to decrease in their successive lots. This improvement would continue until the process reaches a plateau. This paper will address the lot sizing and shipment policy in this supply chain under four circumstances. That is, (*a*) without learning and investment, (*b*) with learning only, (*c*) with investment only, and (*d*) with, both, learning and investment.

## **INTRODUCTION**

There has been an intense amount of research in the area of supply chains. More and more researchers have been investigating aspects such as revenue sharing, quantity discounts and vendor managed inventory in the past couple of years and the theories and practices in this field are not limited to mere inventory control. We notice that researchers have mostly ignored the role of human factors such as screening errors, fatigue and learning. This research gap has been attributed to the uncertainty that arises in complex supply chains (Khan *et al.*, 2014). In this paper a policy for researchers to depend on either learning or investment or both to improve the quality (fraction of defectives) from a vendor in two-level supply chain, is studied.

We assume that in a vendor-buyer supply chain, the buyer institutes a complete inspection of vendor's lots and screens out the defective ones while fulfilling the market demand. This methodology was introduced by Salameh and Jaber (2000) who got a significant attention from researchers in this field, recently. They presented a modified EOQ model to curb the impact of defective items in a vendor's lot. A review of the several articles that have extended this modified EOQ model is presented in Khan *et al.* (2011).

The theory behind learning curves is based on the fact that the amount of time in a recurring task reduces due to experience (Jaber, 2011). It is essential and intuitive that as line workers become more and more familiar with a process the quality of the product improves. Jaber and Bonney (2003) studied how learning progressively improves quality. Jaber *et al.* (2008) used the data from an automotive industry and found that it follows a logistic learning curve. They extended the model of Salameh and Jaber (2000) with this assumption. Khan *et al.* (2010) incorporated learning in the screening process in Salameh and Jaber (2000). They incorporated situations of backorders and lost sales. Khan *et al.* (2012) presented a supplier-vendor supply chain and incorporated learning in two aspects, i.e. vendor's production process and in supplier's quality.

On the other hand, many supply chains opt for investments to improve the level of quality. A trade-off between investments and savings through improved quality has to be determined in this case. Porteus (1986) studied the relationship between quality and lot size in an inventory model. He studied whether the vendor should invest in improving quality or in reducing setup cost or both at the same time. They developed investment strategies for the three options of investment. Lee (2005) presented different investment strategies to select an optimal level of investment. Tsou and Chen (2005) developed an investment model and verified it on a car seat assembly line. They assumed that the mean and standard deviation of a quality distribution for the product can be improved through an investment. Yoo et al. (2012a) discussed whether no, partial, sequential or joint investment should be made on production and/or inspection processes in terms of quality costs. Yoo et al. (2012b) developed an inventory model of defective items with no inspection, sampling and complete inspection options with an investment on production and inspection processes. They extended their model for continuous improvement (CI) investments over multiple periods.

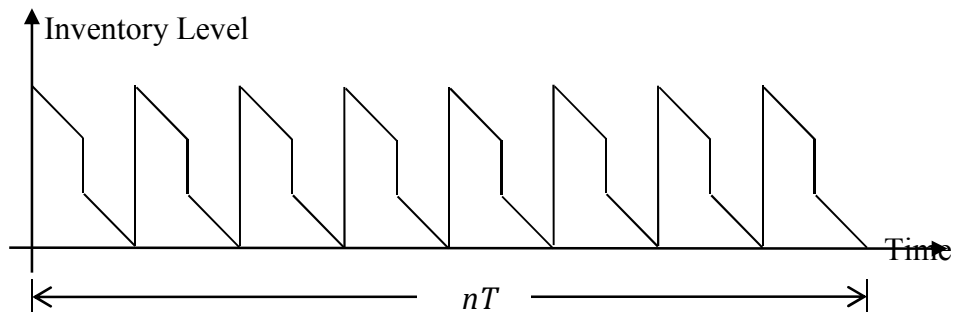
## The MODEL

The following notations would be used throughout the model:

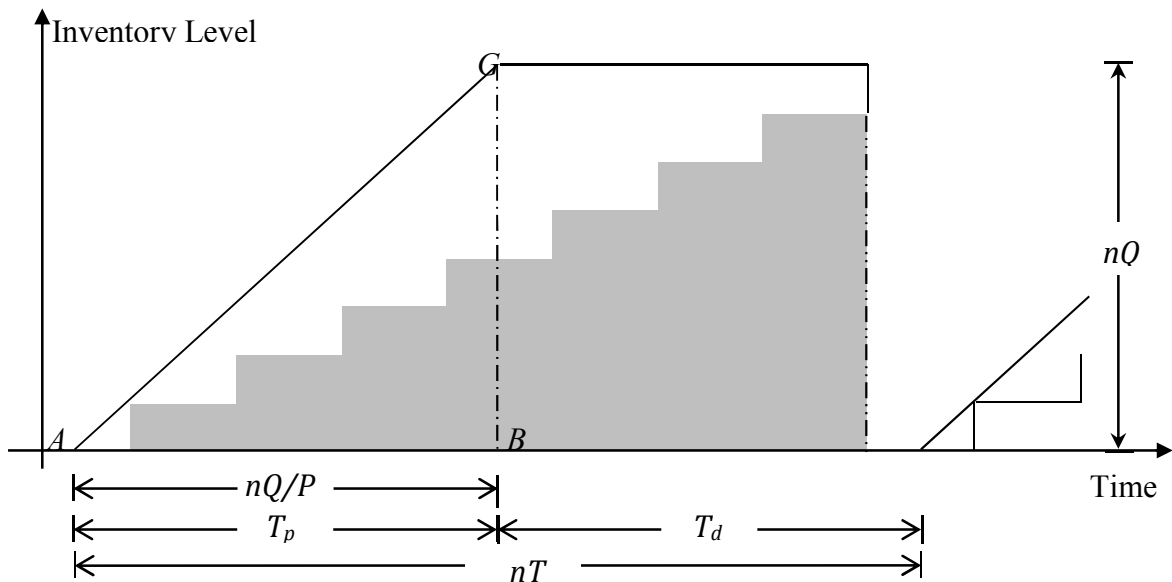
$n$	=	Number of shipments from vendor to buyer in a cycle (a decision variable)
$Q$	=	Size of shipment from the vendor to the buyer (a decision variable)
$T$	=	Time between successive shipments (years)
$d$	=	Buyer's unit screening cost (\$)
$x$	=	Buyer's screening rate (units/year)
$D$	=	Demand for the vendor (units/year)
$P$	=	Vendor's production rate (units/year)
$c$	=	Vendor's production cost per unit time (\$/year)
$g, h$	=	Parameters of vendor's learning in quality
$b$	=	Vendor's learning exponent
$i$	=	An index that represents vendor's learning in quality
$F$	=	Buyer's fixed transportation cost per shipment (\$)
$v$	=	Buyer's transportation cost per unit of the product shipped (\$)
$A_v$	=	Vendor's fixed ordering or setup cost
$A_b$	=	Buyer's setup cost
$h_v$	=	Vendor's unit holding cost for the product
$h_b$	=	Buyer's unit holding cost for the product
$I$	=	Investment function to improve quality
$a, b$	=	Parameters of investment function

We assume that in a vendor-buyer coordination system, the vendor supplies its product through batches of equal sizes in each cycle. A fraction of these items are defective and are screened by the buyer through complete (100%) inspection. The vendor's quality (fraction of defectives) is assumed to improve as a result of a natural phenomenon known as learning (Jaber and Bonney, 2003, Imran et al., 2008). At the same time, the vendor starts investing a little amount to reduce his percentage of defectives in each lot. The aim of this paper is to investigate a coordination policy is influenced by the combined impact of the above two factors

The behavior of inventory at the two stakeholders is shown in Figures 1 and 2, respectively. The shaded portion in Figure 2 indicates the total inventory at buyer's place.



**Figure 1.** Buyer's inventory in vendor's one cycle



**Figure 2.** Accumulation of inventory in a cycle

Using the methodology in Goyal *et al.* (2003) and Khan *et al.* (2014) vendor's total cost in a cycle is the sum of setup, carrying and production costs:

$$C_v(Q, n) = A_v + \frac{h_v n Q^2}{2D} \left\{ (n-1) - (n-2) \frac{D}{P} \right\} + \frac{ncQ}{P} \quad (1)$$

On the other hand, the buyer's total cost is the sum of ordering, carrying, screening and the shipment costs:

$$C_b(Q, n) = A_b + nh_b \left\{ \frac{Q(1-\gamma)T}{2} + \frac{\gamma Q^2}{x} \right\} + ndQ + n(F + vQ) \quad (2)$$

So, the total cost of the two level (vendor-buyer) supply chain in a cycle is

$$TC = A_v + \frac{h_v n Q^2}{2D} \left\{ (n-1) - (n-2) \frac{D}{P} \right\} + \frac{ncQ}{P} + A_b + nh_b \left\{ \frac{Q(1-\gamma)T}{2} + \frac{\gamma Q^2}{x} \right\} + ndQ + n(F + vQ) \quad (3)$$

Bringing vendor's fraction of defectives in this model modifies Eq. (3) as

$$E[TCU(Q, n)] = \frac{D}{(1 - E[\gamma])Q} \left\{ \frac{(A_v + A_b)}{n} + F \right\} + \frac{D}{(1 - E[\gamma])} \left( d + v + \frac{c}{P} \right) + \frac{Q}{2} \left[ \frac{h_v}{(1 - E[\gamma])} \left\{ (n-1) - (n-2) \frac{D}{P} \right\} + h_b \left\{ (1 - E[\gamma]) + \frac{2DE[\gamma]}{x(1 - E[\gamma])} \right\} \right] \quad (4)$$

where  $E[\gamma]$  represents the expected value of vendor's quality. It could also be written as

$$E[TCU(Q, n)] = \frac{DM_2}{Q} \left\{ \frac{(A_v + A_b)}{n} + F \right\} + DM_2 \left( d + v + \frac{c}{P} \right) + \frac{Q}{2} \left[ h_v M_2 \left\{ (n-1) - (n-2) \frac{D}{P} \right\} + h_b \left\{ (1 - M_1) + \frac{2DM_1 M_2}{x} \right\} \right] \quad (5)$$

where  $M_1 = E[\gamma]$  and  $M_2 = \frac{1}{1 - E[\gamma]}$ . The reader is referred to Khan et al. (2014) for further details. Equation (5) would be iterated to find the optimal shipment quantity and the number of shipments in a cycle.

### LEARNING IN VENDOR'S QUALITY

Next, we assume that the percentage of defectives in each shipment, from the vendor decreases following a learning curve. This improved quality may be attributed to the human learning in production and/or inspection at vendor's end. Jaber *et al.* (2008) discovered this behavior in the items of an automotive industry. They showed that the data follows a logistic learning curve of the form

$$\gamma(i) = \frac{h}{g + e^{bi}} \quad (6)$$

Substituting this in Eq. (4), it becomes

$$E[TCU(Q, n)] = \frac{D}{(1 - E[\gamma(i)])Q} \left\{ \frac{(A_v + A_b)}{n} + F \right\} + \frac{D}{(1 - E[\gamma(i)])} \left( d + v + \frac{c}{P} \right) + \frac{Q}{2} \left[ \frac{h_v}{(1 - E[\gamma(i)])} \left\{ (n-1) - (n-2) \frac{D}{P} \right\} + h_b \left\{ (1 - E[\gamma(i)]) + \frac{2DE[\gamma(i)]}{x(1 - E[\gamma(i)])} \right\} \right] \quad (7)$$

This expression would be iterated for ten shipments to have an almost plateaued level of quality. This level of quality  $\gamma(i)$  will be used to optimize Eq. (5) for the supply chain coordination policy.

### INVESTMENT FUNCTION TO IMPROVE VENDOR'S QUALITY

In this section we assume that the buyer pays amount  $I$  for the improvement in vendor's each cycle to improve their quality. This investment function follows the form given by Porteus (1986), i.e.

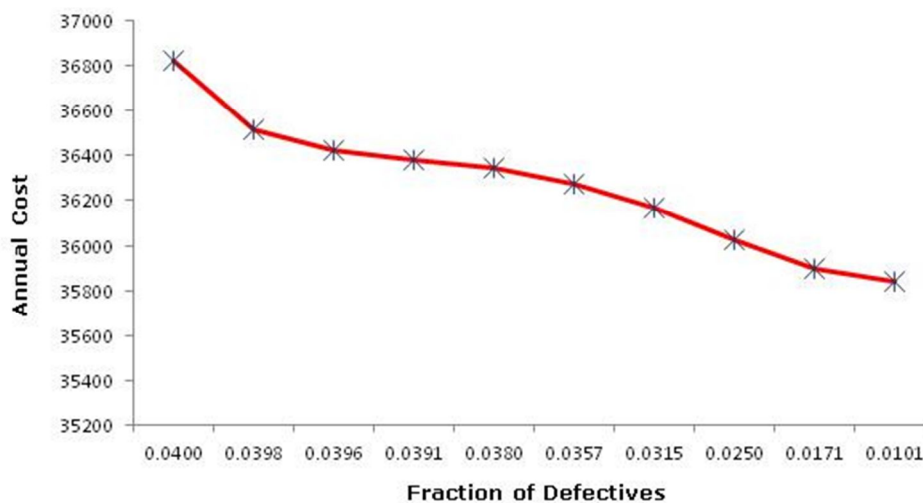
$$I = a - b \ln(\gamma) \quad (6)$$

This investment serves correcting the production processes, training the line workers and giving incentives to quality inspectors at the vendor's plant.

### NUMERICAL EXAMPLES

The following Table shows the input data and corresponding results for the four possible situations describes in this paper. The input data is adopted from Khan et al. (2014).

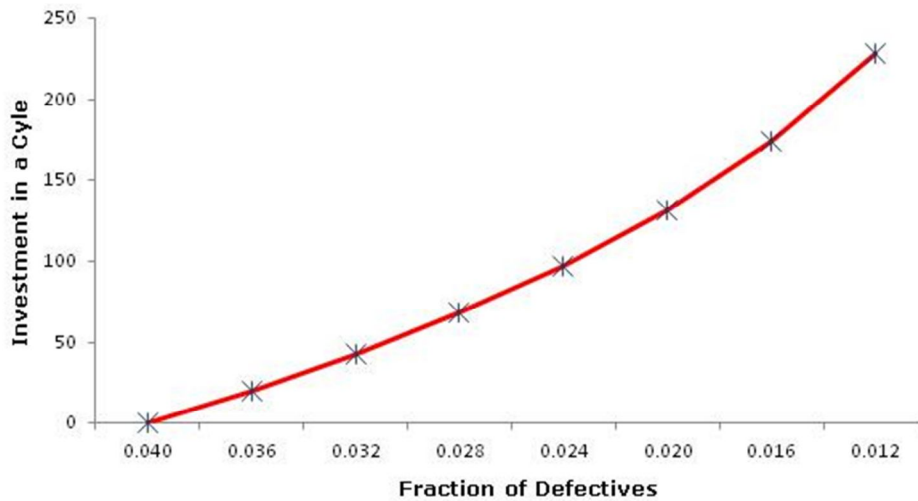
$D$	$P$	$C$	$X$	$A_v$	$A_b$	$c_a$	$c_r$	$h_v$	$h_b$	$d$	$F$	$v$	$b$
1000	3200	100,000	175,200	400	25	200	50	4	5	0.5	25	2	0.8
Units /yr	Units /yr	\$/yr	units/yr	\$/cycle	\$/cycle	\$/unit	\$/unit	\$/unit /yr	\$/unit /yr	\$/unit	\$/shipment	\$/unit	-
							Vendor's Quality	# of Shipments per Cycle	Shipment Size	Annual Cost			
Base Model							0.0400	5	114	36,415			
Learning in Vendor's Quality							0.0101	5	120	35,742			
Investment in Vendor's Process							0.0120	1	577	37,412			
Learning and Investment at Vendor's Facility							0.0077	3	207	36,030			



**Figure 3.** Impact of Learning on Vendor's Quality

It can be seen that learning takes longer and costs lesser than investment to take the quality to a certain level. On the other hand, trying the two measures together gives a trade-off solution.

Figure 3 shows the impact of learning on the values of the fraction of defectives and annual cost of the supply chain. It is evident that with each subsequent shipment or cycle of learning, both fraction of defectives and cost decrease. This is in accordance with the theory of vendor collaboration. A global trend is that a vendor-buyer relationship is transforming from adversarial competitive to collaborative relationships. Competitive supply chains develop a culture that supports the level of long term vendor relationships. Automobiles manufacturers are spearheading the trend and going into closer and long term relationships with selected suppliers.



**Figure 4.** Impact of Investment on Vendor's Quality

Figure 4 shows the relationship between the investment to improve quality and fractions of defectives. The fraction of defectives exponentially decreases with the increase of investment on quality. This investment in quality may be a provision for training to employees, use of technology and new machines, tools, etc. Japanese companies are spending millions of dollars to improve the quality by reducing their defects. Strategies such as lean manufacturing, total quality management and six-sigma are all aimed at defect prevention. Therefore mature companies such as Motrolla, Dell, Caterpillar, are moving toward zero defect strategy by spending huge amounts on quality.

## **CONCLUSIONS**

The objective of this research is to explore the impact of learning and quality investment on fractions of defectives in a two tier supply chain. The results indicate that investment on quality is a quicker solution for controlling the defects. However, there is a cost associated with this improvement. The trade-off in our model provides managers with room to choose the level of investment as per their own circumstances. Fisher (1997) suggested that the design of a supply chain depends on the nature of demand for the products and identified two types of products; i.e. functional (wide range of daily life products) and innovative products (technological products). Following this classification, it could be suggested that for functional products where profit margins are quite low; depending on learning for quality improvement should be viable option for a manager. However, for innovative products that have high profit margin and need continuous enhancement, the manager should emphasize on investment for preventing defects in vendor's lots.

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## **SUPPLY CHAIN AND SUPPLY NETWORK DIMENSIONS: AN EXPLORATORY STUDY**

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### **ABSTRACT**

Typically, research on Supply Chain Management (SCM) focuses inconsistently on the *chain* or the *network* as the unit of analysis. Subsequently, several authors refer to the Supply Chain (SC), or the Supply Network (SN), without a clear indication of their distinction, or consistent consideration of the relevant managerial implications. The pre-conference workshop of ISL 2011 in Berlin focused on understanding the dichotomy of these two important concepts, namely the SC and the SN, to assist in their conception and the implications for future research. The proposed paper aims to report to the ISL community the findings of the 2011 workshop, and continue the debate. Our aim was to identify the competitive relevance and interaction of the SC and SN and their impact on structural flexibility, extending the work by Christopher and Holweg (2011). The paper defines the scope of these two concepts by identifying their different facets and discusses the interdependences that underlie the relevant theory and practice. Realising and appropriately managing the different levels of members' engagement suggests a need for an on-going evaluation of the design of the supply base, to ensure and enhance its competitiveness.

## INTRODUCTION

In terms of Supply Chain (SC) theory development, the emergence of the concept of the concept of the Supply Network (SN) rates as a 'recent' advancement. Although the SN is an important concept and directly relevant to the SC, there has to date been very little research output that has compared and contrasted both of these concepts with a view to addressing their similarities and differences. This paper hence makes a contribution by shedding light on these issues. A key aim is to report back to the ISL community on the results of the ISL preconference workshop in 2011 in Berlin, where the topic revolved around shedding light on the distinction between SC and SN. The two research questions of this paper are thus:

1. What is the nature of the SC and SN concepts?
2. What are the potential links, overlaps and associations between these two concepts?

We focused specifically on the inter-firm level of supply, as the two concepts become more entangled. Issues relevant to their design, configuration and coordination (e.g. trust, relationships, and flow of information) have to be carefully developed, requiring a significant amount of time, effort and resources. The following section provides a brief review of the relevant literature. The research methodology is subsequently presented, followed by an analysis of the key findings. The final two sections discuss the theoretical and managerial implications of this work, the concluding remarks, the proposed future research avenues, and the research limitations.

## THE SHIFT TO THE SUPPLY NETWORK PERSPECTIVE

Cousins et al. (2008) argued that the supply process has traditionally focussed on the dyadic linkages as the unit of analysis; a view that in the late 1980s shifted to the conceptualised level of the SC. The authors further identified the network as the third evolutionary level in the conceptualisation of the supply structure. The network concept has variously been defined by a number of business and management scholars, with common sentiments being the elements of 'relationship' and 'complexity', as indicated in the definitions provided in Table 1.

Table 1: Definitions of the Network Concept

Definition	Author
A network is a constellation of firms linked together in a market by goal congruence and trust in order to encourage committed actors to share benefits.	Jarillo (1988)
A business network is a set of relationships that are connected, showing firms' identity, process and functions that contribute to explaining a dyadic relationship.	Anderson et al. (1994)
A network is a set of self-organising working relationships among firms in order to elicit action and activities and to communicate information efficiently.	Bardach (1994)
A network set is a way to map the structure of relationships, comprised of horizontal ties between firms in the business layer and vertical ties between firms at different levels of layers, including transactions, benefits and knowledge.	Lazzarini et al. (2001)
A network is complex and formed from relationships that range from partnerships to simply buying and selling on a competitive basis or exchanging information.	Tomkins (2001)
A network is a complex adaptive system, where a relationship and a network are managing interactions with others in a two-way process for overall performance.	Ritter et al. (2004)
A network is a form of coordination described by a long-term relationship and information sharing, depending on business interactions	Mikkola (2008)

in the business.	
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As Figure 1 illustrates the evolution of the elements that constitute 'complexity' and their 'interconnected' (but non-linear) network of relationships between various SC members or even actors are also easily transferable to the SN concept. Interconnectedness is of particular importance not least because it is supported by the continuous, multiple and complex interactions between network members in a cross-functional approach (Håkansson and Johanson 1993; Cousins et al. 2008). In terms of the product-focused view of SN complexity, Lamming et al. (2000) proposed a classification, differentiating between SNs for innovative-unique and functional products, and a corresponding degree of product complexity.

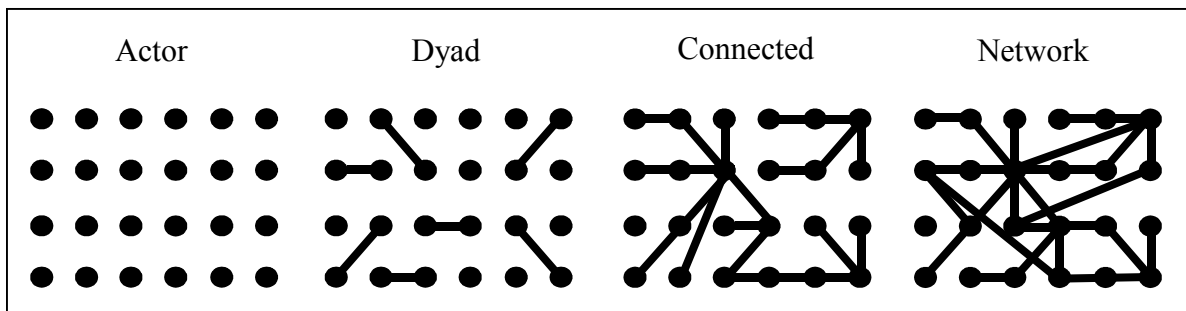


Figure 1: From Supply Chain to Supply Network Management (Ritter et al. 2004, p. 179).

The formation of a network, as illustrated in Figure 1, indicates the interplay between interconnectedness and complexity in the shift towards the network view/perspective. Each dot represents a supply chain firm (or actor) that could be a supplier, a buyer firm, etc. At this point, both the supplier and the buyer start to establish the dyadic relationship by exchanging information and benefits. However, in a SC, it is unusual for a firm to interact only with a single buyer/supplier and to be a member of only one dyad. Firms are far more likely to be connected directly and indirectly with numerous other firms, normally via a non-linear and complex relationship (connected relations). This indicates the need for exploring the differences and similarities between SCs and SNs and the corresponding implications.

In summary, there is a need to further develop and inform our current understanding of the evolutionary, conceptual and practical aspects surrounding such collaborative inter-firm, 'chain-wide' formations. This becomes particularly relevant when one considers the attention that both terms have received in past and especially recent research output.

### METHODOLOGY

The focus group technique was adopted for the collection of primary data (Morgan 1993) during the 2011 International Symposium on Logistics in Berlin. The pre-conference workshop was organized with the aim of addressing the subject of inquiry of this paper. The session attracted 25 academics from 10 different countries representing 3 continents, with a variety of backgrounds and a common interest in the area of logistics and SCM. A brief research protocol was developed, consisting of semi-structured questions aiming to enhance discussion with the participants that would be relevant to answering the main research questions (Healy and Perry 2000).

The workshop followed the methodological approach proposed by Pawar et al. (2005), with the participants being divided into five groups, and assigning questions that were answered using post-it notes, allowing the clustering of outcomes on the wall and further facilitating discussion of key points (see Metaplan, 2013). The session lasted four hours and was facilitated by a moderator, providing the agenda of the 'themes' under

discussion, summarizing outcomes, and generating follow-up questions to probe the groups towards further elaboration, clarification, and/or validation of their findings (Miles and Huberman, 1994).

The first theme focused on identifying the nature of the SC and the SN concepts, and the group participants were asked to establish what these two concepts mean to them. The second theme explored the potential links, overlaps, or associations between the two concepts (SC and SN). The session was audio-recorded (this was made known to the participants) and transcripts were generated. The subsequent analysis illustrates the nature, links, overlaps, associations and the applicability of those themes. After the initial feedback and analysis, an open discussion with the participants followed to allow for any additional points to emerge.

### **ANALYSIS OF KEY FINDINGS**

Participants from the groups acknowledged the difficulty experienced with the variety of terms used in practice, research and teaching, namely SC and SN. One of the participants suggested that:

“There is a huge intersection between these two terms.” [Participant 5]

Although sometimes they appear to be evolutionary phases of the same domain, this is not always the case, resulting in their interchangeable use and confusion. Nevertheless, it was suggested that re-visiting terminologies, their possible developments and intersection, as well as associated useful taxonomies enhance our current understanding, guiding both extant research and practice. It was stated that:

“Both for industry and academic community, terminologies are very important.”  
[Participant 9]

In relation to the first theme (nature of SC and SN), the participants noted that for SC the *focus* is on the provision of final products, and subsequently, the member organisations are involved with the transformation of resources into final products in identified stages. The members of a SC form *relationships in a deterministic manner* in a variety of forms, ranging from basic transactional and arms-length relationships to risk and revenue sharing partnerships. The issue of *power* in the SC relationships was also addressed as an important factor in determining the interaction among the SC members. It was suggested that:

“There is one powerful organisation that sets the scene.” [Participant 21]

As a result of the established power attributes associated to organisations within SCs, the *design and configuration* of a SC encompasses stable structures regarding the relationships of the member organisations. The participants were in agreement that their structure is perceived as linear (e.g. from raw material to the final product), hence not really *complex*, and their management is concerned with the *coordinated flows of information, physical products and finance*. As a result, acknowledging that an organisation can participate in several SCs, it was further reinforced that:

“SCs compete with each other.” [Participant 20]

It was proposed that a SC can compete against another SC when their final products (or services) are competing in the same market, or are direct or indirect substitutes, making their performance as a whole essential to every participant organisation. During the session, it was widely acknowledged that the SC's integration is of paramount importance to enhance the performance of the SC as a whole, and improve its relative competitive position. Since SCs have relatively stable structures with clear business

objectives, their *practices and operations* are predictable, and their integration can be also perceived as *structured*. The key ingredients for enhanced SC performance and competitiveness, as identified by the participants, are *cooperation, collaboration, and coordination* among the member organisations. As a result, an enhancement of the supplier-customer relationships adds value to the SC as a whole and to the final product in particular.

For the SN, the participants suggested that:

“It is like a web of relationships.” [Participant 17]

“A SN is a wider view, or a larger view, of a SC, with satellite organisations. You may have a connection to a company via a supplier that you do not currently need”  
[Participant 8]

The participants argued that a SN has multiple *active and inactive nodes*, hence, it is different from a SC. It is perceived as *dynamic, trust-based and extended*, and hence *complex*, and *non-linear*. The participants suggested that its integration is *ad hoc and unplanned*, making it complex in nature. As a result, its related operations are *unpredictable*, and integration within SNs requires holistic information management. It was acknowledged that similarly to a SC, a SN has also as key ingredients (for enhanced performance and competitiveness), *cooperation, collaboration, and coordination* among the participant organisations. Essentially it was identified that a SN is a web of SCs, with *enhanced complexity* regarding its inter-firm relationships and with relationship management among suppliers and customers emerging as one of the main difficulties in managing the SN.

In relation to the second theme (aiming to identify potential links, commonalities, overlaps, associations between the two concepts), it was mentioned that collaboration, cooperation and coordination (the ‘3 Cs’), combined with relationships, are essential to both SCs and SNs. It was stated that:

“They are both made up of production and transportation activities.” [Participant 1]

As such, it was suggested that:

“There are multiple players in both cases.” [Participant 15]

The exchange of information and value among members is essential within both SCs and SNs alike, and although the SN is built on relationships, still their strategic consideration and management takes place in relation to the effective and efficient provision of products.

It was also suggested that there are active parts of the SN, as well as inactive parts. Subsequently, the actual and potential performance of both SCs and SNs respectively is an important aspect for consideration by continuously assessing the potential sharing of risks and benefits from the interactions. Moreover, in relation to trust, it was suggested that:

“The provision of trust is important to both SCs and SNs.” [Participant 4]

According to the participants, the SN is also important for any focal organisation, i.e. an Original Equipment Manufacturer (OEM), and its member organisations to the wider SN. SN should also identify inactive (namely, ‘satellite’) companies that may not be used continually or constantly. The SN is of paramount importance to active members (i.e. the key SC members), as well as for the inactive members. Evidently, there is a significant

strategic benefit for an organisation participating is a SC, due to the SC's clear business objective, built around specific products. Nevertheless, the participants identified that there is still significant strategic importance for an organisation being considered part of the SN as it was acknowledged that parts of the SN can be activated if needed; hence organisations that participate in a SN in a non-active manner can be called upon.

It was also argued that the SC and SN, and their management (i.e. SCM) should be viewed from two different perspectives: *fact* and *assumption*. It was argued that:

"A supply chain is a fact. The management of the supply chain is an assumption."  
[Participants 1]

Several participants suggested that when the nodes within a SC and a SN are established, the inactive members of the SN should still be identifiable. The way to manage these members though refers to different approaches regarding the type of relationship and the type of provision involved (e.g. information sharing, product and knowledge exchanges). For example, while the type of the relationship between two SC or SN members may be an arms-length or a partnership type, the 3 Cs proposed (namely cooperation, collaboration, and coordination among SC and SN members) may be an assumption, suggesting different anticipated ways of coping with them.

Hence, it becomes evident that although SCs and SNs are different (e.g. in terms of linearity and complexity), they are highly related concepts, as they co-exist, with SCs formed within SNs. Overall, SCs have clear business objectives and they are built around specific products. They are active and deterministic, in the sense that all of their members actively contribute (directly or indirectly) to the development, manufacturing, sale of products, making them stable in nature considering the number of members and the nature of their contribution. Equally, SNs constitute the bigger umbrella within which SCs develop and compete. They have active and inactive parts, making them rather more passive, as well as flexible compared to SCs. Considering and actively managing the SN offers advantages, as SN members can be called upon in case embedded SCs face difficulties.

This analysis has provided the key dimensions and associated characteristics in relation to SCs and SNs, namely their focus, design and configuration, complexity, operations, coordination, integration and ways to enhance competitiveness. These dimensions identified should assist companies in predictive decision making in relation to the SC and the SN, rather than focusing on reactive decision making for the organisations embedded in them.

Based on the previous analysis we define SC as '*a set of activities and relationships that link companies in the value-creation process, in order to provide the final customer with the appropriate value mix of products and/or services*'. Accordingly, SN is defined as '*a set of active members within an organisation's SCs, as well as non-active members to which an organisation relates, that can be called upon to actively contribute to a SC if a need arises*'.

## **THEORETICAL & MANAGERIAL IMPLICATIONS**

The aim of this research was to identify the similarities and differences between SC and SN and their implications for both practice and research. By carrying out a literature review, employing the focus group technique with experts in a workshop setting and conducting subsequent analysis of the findings to clarify the concepts of SC and SN, we provide a contribution to knowledge in this area. This paper sheds light on the relationship between SCs and SNs.

Although all the previously-discussed issues are important for distinguishing SCs and SNs, interestingly, the aspects of 'linearity', 'stability', and 'complexity' were the ones that attracted particular interest during the discussion. The key aspects of coordination and integration generate different challenges for SCs and SNs to be effectively managed. Consequently, the main challenge for managers and academics alike is how to predict these practices within SCs and SNs due to the varying degrees of complexity and the associated challenges in relation to their integration. It was stated that the SCs are formed on contractual bases, reflecting linearity, stability and reduction in complexity.

Based on our analysis, it becomes evident that it is imperative for an organisation to understand and clarify its SC boundaries and linkages, as well as the SN. This will assist any organisation to more effectively and efficiently position itself in the SC, as well as in the SN to which it may actively or inactively participate. With the aid of the distinctive characteristics and similarities between SCs and SNs, organisations are offered with guidance on how to strategically fulfil their expectations and anticipations from their membership in a SC, without overlooking the implication from the wider SN. The decision making process is further assisted by adopting a proactive approach to SCM with the consideration of the relevant SC and SN dimensions.

Identifying the active/inactive role of members of the SN has significant academic and managerial implications. For example, a SN facing a shortage of raw materials or other products due to a crisis in a dyadic collaborative relationship within the chain, or crisis impacting the whole chain (e.g. due to an earthquake, flood, tsunami, volcanic eruption etc.) could revert to sourcing them from other inactive network members/suppliers, minimising any disruption and mitigating any possible risks. Moreover, it was suggested that the identification of inactive members is important when considering Corporate Social Responsibility (CSR) and other ethical issues that may arise from the membership of organisation in the wider SN. It is anticipated that companies will, normally, focus their attention to key/active members and less to satellite/inactive members in relation to these issues and a lack of such consideration can severely impact the SCs embedded within a SN. As a result, it is not deemed sufficient for an organisation to manage only its SC through managing its nodes (e.g. manufacturers, distributors, retails etc.), but instead to have an overarching consideration of how the nodes in its SN act. Such SN nodes can, for example, positively contribute towards SC resilience, or can have a negative impact on CSR issues if neglected. Finally, it was acknowledged that particular attentions should be paid to the cost of maintaining the SN, namely the relationships with the inactive members.

### **CONCLUDING REMARKS, FUTURE RESEARCH & LIMITATIONS**

The SN can be regarded as a multi-faceted entity considering the various interconnected and interdependent issues that need to be considered and balanced. Namely, managing and motivating both active and inactive members with the subsequent risks, complexity and integration required. When dealing with a SN, a complete strategic rethinking is required by industry managers in order to cope with these multiple dependencies. SN is also ideal for current logistics environments which face high turbulence and uncertainty where companies have to activate (and reactivate) alternative, inactive, satellite SN members to secure supplies of raw materials, semi-finished products etc. These environments require companies to be able to follow the "structural flexibility" approach (Christopher and Holweg 2011). The core SC provides the structure/platform of that network whilst flexibility is the outcome of having the ability to activate satellite, inactive members from the rest of the SN when required. Although the traditional SC is not well-suited to accommodate the "structural flexibility" approach, we believe that the SN is well-placed to do so.

Future research could focus on the assessment of the SCs' and SNs' relative performance, considering the issues discussed, including the generation of relevant metrics. This

research could focus on assessing the cost of maintaining the SN, considering its active and inactive parts by modelling various scenarios and costs involved. Future research could also analyse value creation and managing value within a network setting considering that most "value" related research has focused on the traditional value chain concept. It will be particularly interesting to look into the value configuration within a SN and examine how it varies to the traditional value chain. Product, process, information flow, responsiveness etc., to mention a few, could be compared from the SC and SN perspectives, and explore the relevant strategic and operational implications. The proposed avenues for future research should take into account and analyse the views from industry managers and practitioners.

Getting the views from the academic community only could present a clear research limitation of this exploratory study. Furthermore these academics had a common research interest in the areas of logistics and SCM that limits our effort to provide a holistic, overarching and comprehensive conceptualisation for both SC and SN. For example, a multidisciplinary conceptualisation may have been achieved by including academics with a research background in other business, management and social science disciplines such as organisation science, international business, industrial economics, geography to name a few. This is of particular importance considering that the network concept has been analysed extensively in the past by many scholars in these aforementioned disciplines and it has attracted large interest in the SC domain during the past few years only. Nevertheless, we feel that our paper has generated pertinent theoretical and practical insights that will stimulate further research interest in this field of study. Considering the current lack of a comprehensive understanding of the interplay and interrelationship between SCs and SNs, the potential for further research is clear.

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## Section 11 – Applications of ICT in Supply Chains

### SUCCESSFUL ICT USAGE IN SUPPLY CHAINS AND CONTINGENCY: FACTORS AND BARRIERS TO SUCCESSFUL INFORMATION SHARING.

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#### ABSTRACT

**Purpose of this paper:** This paper aims to identify the most critical contingent factors in inter-organisational information sharing in supply chains, and identify how these contingencies are effectively overcome using ICT.

**Design/methodology/approach:** Using qualitative data from two case studies, this paper assesses the information linkages that companies establish with suppliers and customers and assesses the complexity of successful ICT-based information sharing arrangements.

**Findings:** Using a theoretical lens taken from contingency theory, the paper argues that flexible, successful ICT-based communications solutions are contingent upon factors of existing ICT infrastructure, software and file types and organisational culture. From the case studies, the most flexible ICT linkages between organisations in supply chains are the most straightforward; involving the use of singular systems accessed by all partners rather than linked homogenous ICT systems.

**What is of originality/of value in paper?:** The paper utilises up-to-date research findings from 2 commercial areas, where the findings are compared to exemplify the key contingency factors. The paper provides a discussion point with regards to the use of ICT to communicate within supply chains and questions the value of custom-built platforms and software packages.

**Research limitations/implications:** The research is UK based and only considers two companies, and is therefore limited in scope.

**Practical implications:** The research both emphasises an approach to supply chain management that involves an awareness of the ICT capabilities of other companies and their employees and a reassessment of the utility of hierarchical positioning of partners which can be utilised to create flexible inter-organisational communication linkages in supply chains.

#### 1. Introduction

Information sharing between organisations has been identified as a source of major mutual operational benefits between partners in supply chains (Yu et al 2010). These benefits can be in the short term, such as improved forecasting (Seidmann and Sundararajan 1998) to long term operational benefits such as improved and lasting inter-organisational relationships (Premus and Sanders 2008). However, in practice information sharing can be limited in reality between partners and organisations in

supply chains. The barriers to sharing information between partners are typically cost (Uzzi and Lancaster 2003), where the establishment, maintenance and operation of inter-organisational information and communications technologies is identified from the outset as either outright prohibitive or more costly than any benefits that could be realised through the sharing of information (or indeed, identifying which party actually benefits from an arrangement); risk, where the sharing of information results in a dilution of power or of perceived competitive advantage (Uzzi and Lancaster 2003); and perception of the complexity of the task of deciding what should be shared with partners, acknowledging the often changing nature of partnerships and parties in supply chains (Samaddar et al 2006).

Most importantly, there is a necessity to understand what is meant by information sharing; that is, what constitutes the sharing of information as a resource. To elaborate, information in this sense is not just data that is passed between participants that make up a supply chain, but is instead qualitatively something that is of benefit to organisations, and as such is analysed or operationalized in a way that brings tangible benefits to an organisation. This view offers a topological account of the sharing of information, from a basic level of data shared to a higher level of value extracted from the information.

This paper aims to identify what are the key contingency factors in the sharing of information in two supply chains, and what deployments of ICT result in contingencies in the flow of information. Additionally, there is a necessity to identify the deployment of ICT that reduces contingency and analyse what structural features of this deployment result in reduced contingencies.

## **2. Contingency theory in supply chains**

Although contingency theory has its roots in the 1960's and post-structuralist movements of the 1970s and 1980s (Foucault, 1970) in the context of this research the most parsimonious explanation is from Donaldson (2001): Contingency theory argues that *there is no single organisational structure that is highly effective for all organisations. It sees the structure that is optimal as varying according to certain factors such as organisational structure or size. Thus the optimal structure is contingent upon these factors which are termed the contingency factors* (2001: 57). While the application of contingency theory was initially an attempt to understand organisational behaviour, increasingly the approach is used to understand inter-organisational behaviour (for example, Danese 2011).

Donaldson (2001) identifies three critical contingency factors: *size, task uncertainty and task interdependence*, with the contingent factors emerging from these categorical contingency areas. There could be contingencies emergent from a singular factor, or from a multitude of factors across these areas; but the effect of a misfit between structure and performance would be the result in the event of contingencies affecting performance. In the context of inter-organisational information, one can begin to assess the potential contingencies that may emerge from these three meta-categories. As the size contingency relates to the number of organisational members that are involved in a process, a process that has too many persons involved, or too few, may be affected by these contingencies. This may impact on the performance of the organisation particularly if there is a lack of fit between the ICT skills of the individuals involved and the task. This

concern is more accurately a contingency that derives from task uncertainty, where contingencies made up of technology, technological changes and the environmental instability that these disruptive innovations can induce are considered. For task interdependence, the manner by which activities are connected with one another are considered. This is pertinent in the context of this paper, as the flow of information between parties would be a reflection of the extent and quality of the relationship between organisations and difficulties in this flow would be a contingency that would affect performance in an inter-organisational context such as a supply chain.

In addition to the application of contingency theory to supply chain management, some recent research has utilised the contingency approach to assess information sharing itself as a contextual factor in supply chains, and how information fit effects supply chain operations (Premkumar et al 2005). The factors identified include supply chain context and organisational culture (Roh et al 2008), nature of relationships with partners (Samaddar et al 2006), business characteristics, product features and market dynamics (Vanpoucke et al 2009) and relational characteristics (Spekman et al 1998).

While information sharing has been identified as an area for further research, there has been scant research into the deployment of ICT as a contingent factor in the sharing of information, and the role of ICT as a key facilitator in sharing information in the context of contingency, and this is what this paper addresses then the aims of the paper are to address a significant gap in the literature. It seems intuitive to suggest that the technology that overwhelmingly enables inter-organisational communications in the twenty-first century should be considered as a major contingency factor in the sharing of information in supply chains and therefore in the functioning of supply chains in general, but this is in opposition to the research that makes up the literature. Therefore, the primary research questions in this paper are:

*RQ1: what are the contingency factors regarding information sharing in inter-organisational supply chains?*

*RQ2: what kinds of ICT deployment can negate these contingency factors?*

### **3. Research method**

These research questions were tested through two case studies that are positioned as comparisons between one another in regards to the use of ICT. A multiple case study research method was adopted, because it is particularly suitable when we explore the "why", "what" and "how" research questions and examine contemporary events (Voss et al. 2002; Yin 1994). Since the primary purpose of the research is exploratory in nature, a multiple case study approach was considered appropriate as the research attempted to "provide new conceptual insights by investigating individual cases for an in-depth understanding of the complex external world (Wacker 1998)".

The comparative case study method used in this paper utilised case studies with two major organisations. Firstly, Company A is a major freight forwarder and third party logistics provider that operates on 6 continents, and has major operations in the UK. The organisation operates over 500 branches in 90 countries, and employs 15,000 people worldwide. Their partner in the case study undertaken here is a major telecommunications technology and infrastructure provider, that serves 45 of the top 50 telecommunications networks in the world with technological solutions. The supply chain

between these two organisations and the UK customers of the telecommunications partner forms the basis of the first case study. The second company studied is a major civil engineering and construction company, employing over 4,500 employees in the UK. The case study focuses on one civil engineering project based in Wales.

This comparative approach was used as a means to validate the research questions' implicit prediction that deployments of ICT that are designed and utilised with the minimising of contingent factors as a feature in the planning of systems in supply chains will realise greater efficiencies and less adjustments to operational arrangements during projects. The data collection method is summarised in Table 1.

Case examples	No. of site visits	No. of system demonstrations	No. of interviews (face to face)	List of Interviewees
Case A	3	4	8	<ol style="list-style-type: none"> <li>1) Global warehouse &amp; distribution manager</li> <li>2) Global Corporate governance manager</li> <li>3) UK Head of logistics manager</li> <li>4) Warehouse Manager,</li> <li>5) Inbound Processes manager,</li> <li>6) Outbound manager</li> <li>7) Reverse logistics manager</li> <li>8) IT system development manager</li> </ol>
Case B	2	2	8	<ol style="list-style-type: none"> <li>1) Sector director</li> <li>2) Innovation manager</li> <li>3) The project manager</li> <li>4) Chief quantity surveyor</li> <li>5) Document manager</li> <li>6) Office manager</li> <li>7) Systems performance manager</li> <li>8) Internal auditor</li> </ol>

Table 1: Summary of data collection methods (source: authors)

We have also developed a research protocol to ensure that data required was collected in a systematic, rather than ad hoc manner. The protocol developed structured the interviews with participants, and informed the observational process.

#### 4. Case study 1

Company A has been working with Partner X for 1 year, and is responsible for managing inbound, warehousing and outbound logistics activities for Partner X. The routine operating procedure and the information flow is as shown in Figure 1 where PA denotes Company A and HW denotes Partner X.

While this system is seen overall as working well, intra-organisational communications were cited as a major problem during interviews with regards to inbound logistics and road freight from Hungary factory. The inbound process from Hungary is as follows: an email from Hungary arrives with the shipping advice. This identifies the number of cases and estimated date of arrival. This is forwarded to Partner X who upload the information to their stock inventory system, that generates an EDI link that updates Company A's warehouse management system. The warehouse management system generates the

packing list which is used on goods arrival. Ideally, the packing list dictates the packing of items into trucks in Hungary, but this is often not the case and creates delays with recording the stock available when the stock arrives at Company A – exemplifying the visibility contingency.

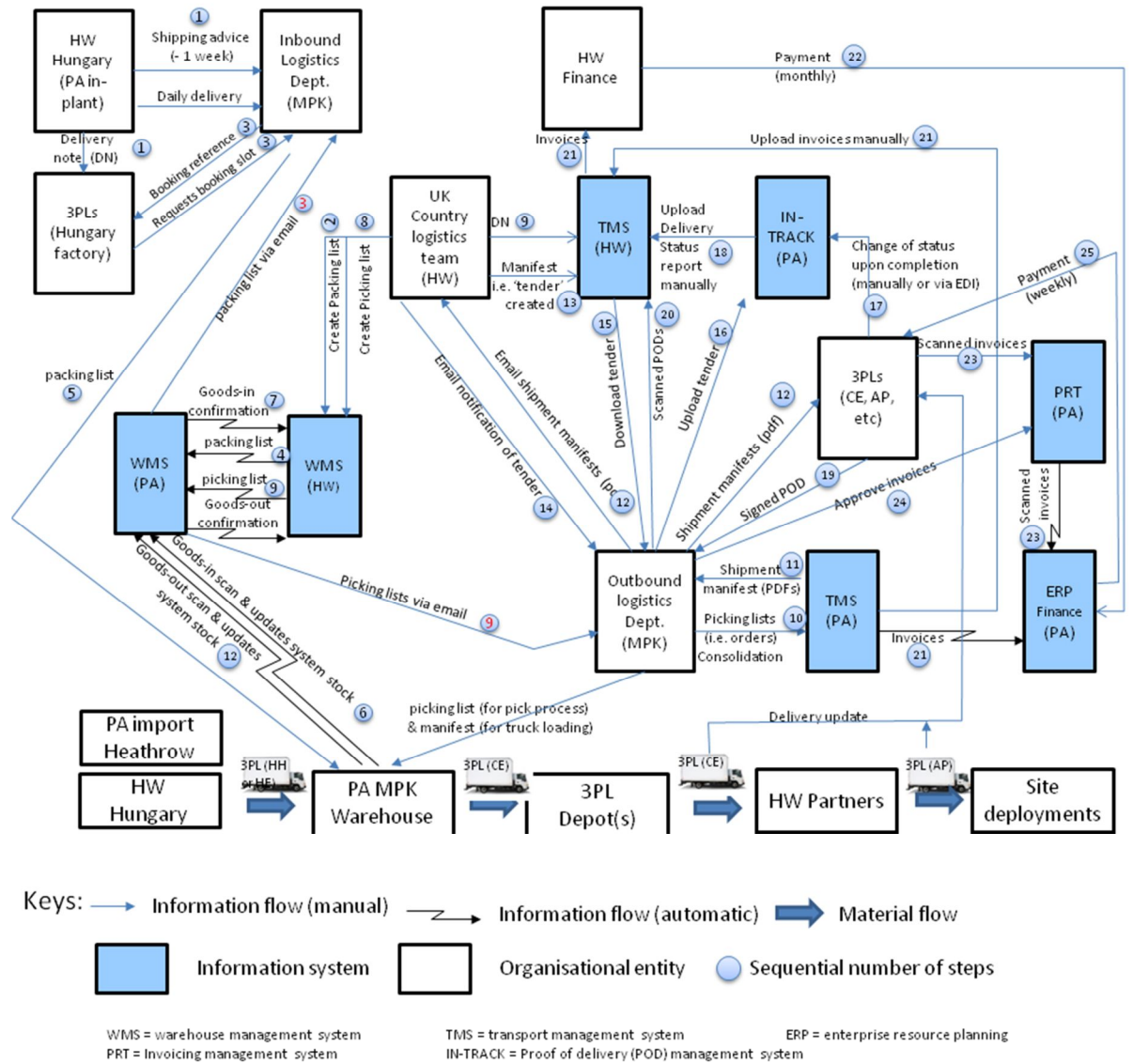


Figure 1: Information flow of case A’s supply chain (inbound, warehouse and outbound) (source: authors)

Currently, there is no vehicle tracking for inbound or outbound operations, which is a particular issue regarding deliveries from the Partner X factories in Hungary. Typically, deliveries from these sites have a 5 day delivery time, but rarely take longer than 3. While the Company A transport management office (based in Europe) has the capability to accurately forecast delivery times (e.g. the arrival times of ferries carrying lorries into ferry ports in the UK) this is not currently shared. On delivery, subcontractors update order delivery record either by phone or email. Company A then updates Partner X’s records using an in-house transport management system which is linked to Partner X’s through a dedicated B2B e-link.

The scanning of items on arrival is itself an issue, as there are delays due to loss of signal which can result in scanning times of 4-5 minutes per item. This is compounded by data packet loss in the scanning system and between UK and Germany (where the central Company A servers are hosted), and server drop-offs when accessing central main servers. This, coupled with a lack of order visibility, creates issues. The mechanism and decision making process of the grouping of items into packing list items by Partner X (transmitted via EDI) is also unknown. A daily report of outbound shipments from Hungary is made available, but its applicability is limited. In this example, timeliness or the time to accrue relevant information and the technological infrastructure of information capture are contingency factors in this chain, deriving from the functional organisation of consignments and the process at Company A.

The process of the outbound logistics function was outlined as follows. An email is sent from Partner X to Company A with an attachment (purchase order requirements) of the customer order, that is checked for errors before being processed and sent to the warehouse. The Company A B2B system links into the Partner X inventory system, informing that system of the stock in the warehouse. The details of the item are then sent for picking, and the items are dispatched either for collection by a daily trunk vehicle or by Specialist third party delivery agent if the item is for "last mile" i.e. it requires specialised engineering on site. The Proof of Delivery (POD) must be returned by the haulier within 48 hours. The main bulk carrier returns the POD every day, while others return by email e.g. a scanned PDF. Company A upload the completed delivery date and actual time of arrival into Partner X POD management system (based in Hong Kong). That system will send an alert for any POD outside 48-hour window.

The intra-organisational communications (both in the context of ICT architecture and procedures) are a major problem, as the major issue is visibility instantly especially the Hungary/Company A supply chain. This indicates contingencies on the availability of information and the selection of what information to share between partners, and the form of information that is shared. While there is information sharing occurring (and a model of information sharing with the ocean and air supply chains that does work), the information sharing is currently inadequate or lacks fit between the needs of Company A and the expectations of Partner X. This can be attributed, as a contingency factor that derives from Donaldson's (2001) categories, to task interdependence as a contingency factor.

The organisations have a clear common goal, but the use of independent, homogenous systems hosted at each organisation that communicate through a B2B link means that there are clear contingencies in the quality of data received (amount, accuracy and appropriateness) and the fit of that data to the operational aspect of the supply chain. In this case, the contingency preventing information sharing is not the desire to share or inter-organisational factors such as trust, but the appropriateness of the mechanisms and selection of information to be exchanged in light of the task to be achieved. Much of the exchange of information takes place without dedicated systems, employing an ad-hoc approach where less-specialised but readily available tools such as email or Excel spread sheets are used, but this creative use of existing technology does not address the specific needs of the supply chain, although the speed of information flow is maintained. While the flow of information is undoubtedly assured though, the quality of fit of the information to the operational parameters of the supply chain and task are not addressed, and so three key contingency factors regarding information sharing can be

identified in this case: the availability and provision of information on the task; the appropriateness of the information shared for the task undertaken; and the provision of an adequate technological infrastructure within and between organisations for the provision of information sharing.

## **5. Case Study 2**

The Road Y project begun in 2009, and anticipated handover to the client is for November 2013. From 2009 – 2011, the project was in the planning phase, where Company B worked with Designer E and the clients' own designers. Designer E primarily worked on the design of the bridges for the project, the client worked on the road works, drainage and landscaping. Drawings at that stage were produced in both 2D and 3D, with the majority being sketches. This is a manual, non-electronic form of drawing, with no Computer Aided Design (CAD) used by the client (and no CAD software installed on the computers at the Company B site office). Drawings are digitised through scanning, handled by an outside agency.

Document handling is the key to the operations of the project. Designer E uploaded their drawings to the intranet system for Company B which acts as a central repository for all project information. Designer E (and other relevant parties external to Company B) have limited access to the system, allowing for uploads and removal of old drawings, and access to other documents that are important to their design work. Designs were reviewed in weekly design review meetings with Company B, Designer E and the client. Any revisions to drawings are allocated file names consisting of numbers, any final drawings were named with letter combinations. Some review meetings also necessitated input from Company S (steel producer) and Organisation T (the Railway maintenance and operator), and so necessitated extra planning. Documents were printed for review as well as being made available on the Company B intranet site through an email link (which allowed access to the single document only). Both Organisation T and Company S had limited access to Company B's intranet for the project duration, to documents pertinent to their operations. Email links of this kind cut down on the size of email attachments and allowed for more rapid information sharing.

Every document on Company B's intranet system has a unique reference number, insuring all digital assets are recorded and allocation of access can be monitored by reference number. Documents are also active i.e. information on access and links to revisions can be embedded in the document. Subcontractors were given one-time access for documents and physical copies, although the intranet access is contingent upon the appropriate technological infrastructure being available with the contractor. Large, important subcontractors also produce drawings that are uploaded to Company B's intranet. Of the 50 or so subcontractors on the project, approximately 70% are SME's and these rely on paper copies of plans and drawings. Future developments may prioritise subcontractors with appropriate data handling capabilities. This level of control in the handling of information minimises the contingencies of amount of information and appropriateness of information, as Company B shapes the information flow for the needs of the individual partners based on their technological abilities and operational function in the project.

Requests for information go through document control. These are usually requested if there are gaps in the designs, or site team issues. The design co-ordinator is the first



point of contact, who then collates the request and passes it to document control if new or different documents are needed to be issued to on-site staff. Approximately 500 requests have been made to date on the project. Documents are usually issued through email links to Company B's intranet to save time and print expense. These documents form the core of the supply chain for the project, with the quantity surveyor and partner organisations basing their orders for supplies and plant on the most up-to-date plans available. The use of this system has allowed for just-in-time plant hiring for the project and for detailed forward planning and forecasting of supplies, which has reduced overall costs and the timescale for completion of the project as allocating room for storage of plant and supplies has been minimal, and planning of major deliveries of inventory has included long lead-in times that have been integrated effectively into the overall project timescales. Again, the contingent factors of appropriateness and amount are controlled, along with timeliness as the centralised control means that documents and links are provided uniformly, in line with the overall project timeline and with multiple information sharing techniques used to insure all documents are issued on time.

In this case study, the intra-organisational communications and inter-organisational data flows and communications were well defined and planned from the outset. Expectations of partners with regards to information handling and capabilities are realistic, if sometimes causing frustration. The intranet is undoubtedly the key application in the data flow of the project. Acting as a quasi-cloud solution (although not cloud based) it allows for the configuration and reconfiguration of information sharing between partners and Company B, and leverages flexibility into the sharing of key information and documents. The intranet also allows for swift changes to plans to be executed and communicated to all relevant partners through relatively little labour on the part of the project team. Any contingencies in information sharing were identified and defined at the outset of the project, and a stable and recognised platform for the storage and sharing of information was used from the outset. This platform limits the contingent factors in information sharing by replacing homogenous systems that are difficult to link with a single system with access allocated as required to project partners, in line with the project plan. This system requires human intervention, which means it is not a solely ICT based system, but this management element does not inhibit the sharing of information as clearly defined communications channels have been established prior to the project. The use of a single system dictates clear protocols for the encoding, storing and sharing of information that insures effective sharing across the project.

## **6. Conclusions**

The two case studies illustrate two approaches to supply chain management and project management that not only differ in information sharing efficacy, but also in organisational approach. In Case 1, Company A has developed new SOP's at the behest of Partner X, and as such does not occupy a position of control with regards to the development and design of an information sharing architecture for the effective flow and selection of information appropriate to the operational needs of the supply chain. In contrast, in case 2 Company B has occupied a position of control over the architecture of the sharing of information between partners and their own intranet acts as a repository and source of all the key information on the project. This control and single system for sharing information allows the key contingency factor of the appropriateness of the information for the task to be controlled by a single key partner in the project. In case 1, the position of Company A as a conduit to the functions of Partner X rather than the

leader of the supply chain information sharing has allowed for an operational reality of separate information systems and flows to develop, which causes problems at the operational level. The key to avoiding this informational contingency would be – as seen in case 2 – control over the information flow by one partner allows for the design of a simple system where the maximal utility in the context of the project itself becomes the key consideration in the sharing of information, minimising the contingency factors of appropriateness, amount, accuracy and timeliness from the major task interdependence contingency identified by Donaldson (2001). This system is, however, difficult to implement as the realities of inter-organisational communications are that expensively-delivered ICT systems demand use: to cede control to a partner is to negate the investment made in one's own systems. The clear hierarchical system employed in case 2 avoided the issues that came from the ceding of control in case 1. However, in these cases it can be seen that control and an effective sharing infrastructure can avoid contingencies in information sharing in inter-organisational logistics, projects and supply chains.

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# THE POTENTIAL IMPACTS OF ELECTRONIC ONBOARD RECORDING DEVICES ON TRUCK DRIVER WORKLOAD AND TURNOVER: RESEARCH IN PROGRESS

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## ABSTRACT

Trucking companies in U.S. are increasingly using in-cab information technology (IT) such as the Electronic On-board Recording (EOBR) devices to improve their efficiency. EOBR, while offering potential benefits, are being cited as a factor that may cause undue learning and monitoring related stress and negatively impact job retention. Research on technology caused job stress (technostress) in other occupations has shown that IT introduction in jobs can create stress and turnover. This study examines the technostress inducing aspects of EOBR and how these factors affect truck drivers' turnover intention. Moreover, research on usability of IT demonstrates that poor IT design can lead to fatigue, exacerbating work exhaustion. We propose that learning to operate an EOBR and being monitored by an EOBR stresses drivers by increasing their perceived workload that in turn leads to work exhaustion and turnover intention. We further propose that enhanced usability support provided by an EOBR reduces the impact of drivers' work exhaustion, indicating that the design of IT may play a key role in reducing the stress associated with learning and being monitored by IT. In this research in progress paper we discuss our preliminary findings.

## Introduction

According to the American Trucking Associations, the driver turnover rate averaged 81 percent in 2011, causing trucking companies millions of dollars in driver replacement costs. Cassidy (2011) reports that on average U.S. truckload carriers are replacing 57 to 89 percent of their drivers workforce annually, at a cost estimated *between* \$3,000 and \$8,000 per driver. Prior transportation and logistics research centered on driver turnover has identified various determinants of turnover, such as driver demographics (Beilock & Capelle, 1990), relationship with top management (Garver, Williams, & Taylor, 2008), relationship with dispatchers (Garver et al., 2008), pay (Garver et al., 2008; LeMay, Taylor, & Turner, 1993; Williams et al., 2011), personal safety (Williams et al., 2011), time at home (Williams et al., 2011), work environment (De Croon, Sluiter, Blonk, Broersen, & Frings-Dresen, 2004), and fairness in work practices (Williams et al., 2011).

Like in other countries, the US Federal Motor Carrier Safety Administration (FMCSA) is considering mandating truck drivers use of EOBR to track compliance with hours of service rules and decrease the risk of fatigue-related crashes (FMCSA, 2013). While prior literature has found IT equipment to impact driver's turnover intention (LeMay et al., 1993; Williams et al., 2011), the theoretical justifications behind this relationship has not been empirically examined. Drawing on theories of stress, recent research on technostress (stress due to IT) has shown that factors about IT can create stress and have an impact on organizational processes and outcomes, including perceived work overload, demoralized and frustrated users, fatigue, loss of motivation, and job dissatisfaction (Ragu-Nathan et al. 2008).

Other studies of trucker job satisfaction have focused on the 'equipment' that drivers are provided to accomplish their job (LeMay et al. 1993). Equipment includes tractors and trailers, loading and unloading devices, communication devices and today includes in-cab IT such as the Electronic On-board recording (EOBR) devices. Past studies show that having good, reliable equipment can improve driver safety and decision making, increase productivity and drivers' job satisfaction (Stephenson & Fox, 1996). It would follow then, that drivers will appreciate well-designed EOBR that are highly useable, making their job easier and safer. Hence, EOBR also has the potential to mitigate driver work exhaustion.

In this paper, we examine the relationship between EOBR and driver's stress, work exhaustion, and turnover intention. We also explore the somewhat countervailing potential that highly usable EOBR helps mitigate work exhaustion.

### **Theory and Hypotheses**

According to the theory of transactional model of stress, stress occurs as a result of an imbalance between stimuli, threat or a demand placed by the environment and the inability of the individual to respond to the demand or the anticipation of a negative consequence of the demand. Demands that induce stress are known as technostress creators (Tarafdar et al., 2007). When the individual does not have the resources to deal with the technostress creators, the development of stress manifests itself in the form of a strain which can then lead to organizational outcomes such as job dissatisfaction. Technostress inhibitors are variables that have the potential to influence the development of strain by directly mitigating the effect of strain or acting as moderators for the technostress creator-strain relationship.

We propose two constructs that act as technostress creators due to usage of EOBR. These are IT learning stressor and IT monitoring stressor. IT learning stressor is the stress associated with learning how to use the EOBR efficiently to perform their job duties. Ragu-Nathan et al (2008) argued that IT learning stressor can be a source of stress because workers feel inadequate with regard to their computer skills forcing them to spend time and effort in learning and understanding technologies. IT learning stress can be more prominent among truck drivers because they are generally considered to have lower levels of technology skills compared to the white-collar professionals. Working with the EOBR forces truck drivers to spend extra time and effort in learning how to operate the EOBR efficiently, thus leading to higher work overload. This work overload then translates into higher job demand leading to elevated stress, driver fatigue and reduced efficiency. IT monitoring stressor refers to the stress experienced by individuals due to the obtrusive nature of technology. EOBR collects data on the speed, miles per gallon, braking, idling, log in and log out time, driving time, location and many other parameters. Managers usually use this data in order to determine the driving behavior of the driver. This constant form of electronic monitoring is likely to be stressful when it is used to enforce compliance with performance standards that workers have difficulty meeting. Under such conditions, workers may experience stress through work overload, negative computer/supervisor feedback and threat of job loss thereby causing work exhaustion. Therefore we hypothesize

H1: The positive relationship between an IT learning stressor and work exhaustion is mediated by work overload.

H2: The positive relationship between an IT monitoring stressor and work exhaustion is mediated by work overload.

Technostress inhibitors represent the situational variables and can be described as IT's capability to reduce the effects of technostress by directly mitigating strain or acting as moderators. In this study, we propose IT usability support as a situational variable. Usability support refers to the ease through which drivers are able to use the EOBR effectively to complete their daily tasks. A well-designed truck IT equipment can make a significant difference in the working conditions for a truck driver. An intuitive design of EOBR reduces the cognitive load associated with comprehending and using the equipment. Furthermore, it also makes drivers feel competent with using EOBR thereby helping them accomplish their tasks faster and more efficiently. Therefore, we propose

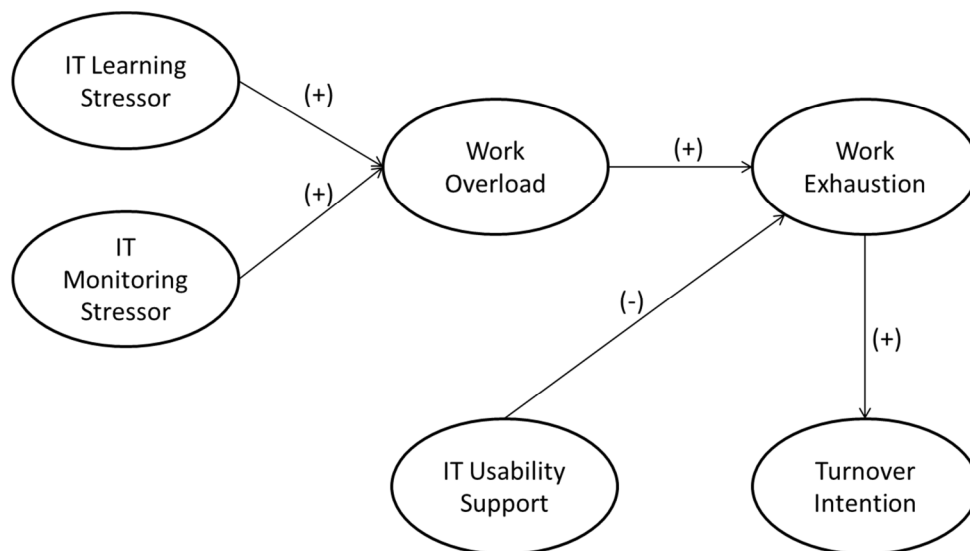
H3: IT usability support is negatively associated with work exhaustion.

### **Work exhaustion and turnover intention**

Lastly, this study looks at the effect of work exhaustion resulting from work overload on a driver's turnover intention. Turnover intention is defined as a voluntary intention of employees to quit their organizations (Ahuja et al., 2007; Knudsen et al., 2009; Moore, 2000). The majority of studies investigating the influence of work exhaustion on turnover have demonstrated that employees with high level of work exhaustion are more likely to voluntarily quit from their jobs than employees with lower levels of work exhaustion. Therefore, we hypothesize

H4: Work exhaustion is positively related to driver turnover intention.

## Research Model



## Mediation Hypotheses

- H1: IT Learning Stressor → Work Overload → Work Exhaustion  
H2: IT Monitoring Stressor → Work Overload → Work Exhaustion

Figure 1: Research model

## Research Method

Data was collected both quantitatively using surveys and qualitatively using interviews. Data were gathered from a sample of full-time truck drivers working at a large US intermodal trucking company located in mid-south U.S. First, we developed an initial version of survey questionnaire based on prior literature on technostress and driver turnover. To establish field-based instrumentation validity, we interviewed one manager, one supervisor and four dispatchers from the company. During these interviews, we asked the interviewees on the relevance and clarity of the questions within the context of IT use situations operated by truck drivers to complete their daily tasks (Boudreau, Gefen, & Straub, 2001). Based on their feedback, the survey was revised and a pilot test was then conducted with 20 truck drivers for increasing the instrument validity and internal consistency. The data from the pilot test were used to check the psychometric properties of the scales and then reviewed to look for any inconsistencies or unexpected answers. The questionnaire was corrected for any irregularities and sources of errors. The revised version was launched for the main survey<sup>1</sup>. A \$15 Wal-Mart gift card was given as an incentive to every driver who completed the survey. Both company drivers and independent owner operator drivers were surveyed using an online questionnaire that was installed on computer terminals that drivers visit to scan and submit their daily bills. In total, data from 140 truck drivers was received. Responses to all the constructs were obtained using four items. Each item was measured on a 7-point likert-type scale ranging from 7 (strongly agree) to 1 (strongly disagree). Items for IT monitoring stressor and IT usability support were self-made. Items for IT learning stressor were adapted from Ayyagari et al. (2011). Items for work overload and turnover intention

<sup>1</sup> The final survey instrument is available from the authors upon request.

were adapted from Moore (2007). Table 1 in the appendix contains the cross loadings between the variables used in the study. Further analyses using PLS will be conducted to determine the structural model and final results.

### **Discussion and Implications**

The anticipated contributions of our paper are three folds. First, the findings of this study should identify IT's capability of inducing stress to truck drivers due to learning and being monitored by EOBR. This would significantly extend the present understanding of how EOBR can have a detrimental effect on the psychological health of truck drivers. With regard to the practical implication, we anticipate that managers should introduce the EOBR to drivers in a way where EOBR monitoring and learning to use the IT is not viewed in a negative way or as overly controlling. Second, the expected results of the study should indicate that the design of EOBR negatively impacts drivers' work exhaustion thereby showing that the usability of EOBR may help in reducing the work exhaustion caused due to stress inducing factors of EOBR. Future research should examine specific features or structures of EOBR that drivers are most comfortable or uncomfortable with so that EOBR vendors can incorporate them when designing the next generation EOBR. Lastly, it is proposed that an increase in work exhaustion positively influences drivers' turnover intentions. This research should help companies and policy makers understand the negative cognitive responses of truck drivers to in-cab IT introduction and to carefully examine any rules or regulations regarding the use of IT before widespread release.

### **Conclusion**

The purpose of this research is to theoretically examine how the use of EOBR impacts truck drivers' turnover intention. Using the transactional model of stress, this paper seeks to identify learning EOBR and being monitored by EOBR as two important stress inducing aspects of EOBR that impact driver's work overload which in turn positively influences their work exhaustion. Furthermore, the research on usability of IT proposes poor IT design can lead to work exhaustion which also exacerbating turnover. This relationship will also be explored.

### **Acknowledgement**

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## Appendix

	<b>LS</b>	<b>MS</b>	<b>WO</b>	<b>US</b>	<b>TO</b>
<b>LS1</b>	.836	.222	.225	.059	-.099
<b>LS2</b>	.870	.181	.144	.090	.055
<b>LS3</b>	.894	.112	.164	-.051	-.016
<b>LS4</b>	.851	.144	.214	-.102	.050
<b>MS1</b>	.164	.819	.156	.065	.040
<b>MS2</b>	.195	.902	.181	.017	.031
<b>MS3</b>	.148	.880	.224	.091	.030
<b>MS4</b>	.156	.892	.203	.082	.046
<b>WO1</b>	.239	.183	.811	-.128	.182
<b>WO2</b>	.160	.263	.858	-.019	.160
<b>WO3</b>	.152	.232	.885	-.082	.127
<b>WO4</b>	.282	.142	.843	.014	.066
<b>US1</b>	-.054	.098	-.073	.911	-.142
<b>US2</b>	-.016	.091	-.094	.933	-.074
<b>US3</b>	.080	.019	.017	.933	-.080
<b>US4</b>	-.020	.033	-.009	.915	-.137
<b>TO1</b>	.063	.319	.224	.018	.641
<b>TO2</b>	.001	-.048	.046	-.150	.955
<b>TO3</b>	-.036	-.028	.070	-.154	.957
<b>TO4</b>	.052	.257	.358	.122	.576
<p>LS - IT Learning Stressor, MS - IT Monitoring Stressor,            WO - Work overload, US - IT Usability Support, TO -            Turnover Intention</p>					

Table 1. Factor Analysis and cross loadings

# LOGISTICS CENTRES IN SERBIA: FRAMEWORK AND POTENTIAL BENEFITS OF ICT APPLICATION AND INTEGRATION

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**Paper type** Conceptual paper

**Purpose of this paper** – The purpose of this paper is to create and propose fundamental platform for establishing framework of Logistics Centres (LC) allocation in Serbia and to review potential benefits from ICT sector.

**Design/methodology/approach** – The paper is conceptually focused on two objectives. The first objective is to provide review of various approaches as well as new proposals concerning geographical location of LC in Serbia, with special focus on those in Autonomous Province of Vojvodina. The second objective is to explore integration of Information Communication Technologies (ICT) and LC operability in order to point out how modern technologies affect logistics operations, including management, monitoring and forecasting of logistics activities in material and information flows.

**Findings** – Two entirely new scenarios, concerning LC allocation, are explained: "Scenario Pillar" and "Scenario Corridors". The first scenario is based on regional development and economic strategy of Serbia, while the second extends the existing scenario by introducing additional factor – Corridor XI. Very important aspect – network of Corridors (VII, X and XI) across Serbia is highlighted as potential support and initiator of logistics establishment. Also, integration of Serbia into European logistics system is not possible without the use of modern ICT technologies. Thus, establishing logistics framework is suffused with various ICT solutions which improve LC operability. This paper focuses on Geographic Information System (GIS), Global Positioning System (GPS), and Radio Frequency Identification (RFID). These technologies enable warehouse material and information flows optimization, vehicle tracking, while the software support is based on GIS platform. As a result, Logistics Centres Database (LCD) system is proposed. LCD presents a new, original way to explore, analyze, share, and synthesize grouped data and provides multiple benefits.

**What is original/value of paper** – The paper offers a brand new concept of ICT and LC integration and application. Such an approach hasn't been suggested so far. New ideas and directions may emerge regarding establishment of logistics in Serbia.

## 1. INTRODUCTION

Logistics Centres (LC) are complex facilities with multiple functions, including transshipment yards, warehouses, wholesale markets, information centers, exhibition halls and meeting rooms, etc. (Taniguchi et al., 1999). Also, a LC is the hub of a specific area where all activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out, on a commercial basis, by various operators (Europlatforms EEIG, 2004). Each section of the LC has function to perform specially-assigned operations. Many sectors are designed to meet various needs of modern logistics and customer' demands. In order to achieve a full potential of LC operability advanced information systems are needed. Advanced information systems help implement algorithms and heuristics to develop more efficient client routing and scheduling systems for pickup and delivery trucks in operative areas (Taniguchi et al., 1999).

Firstly, this paper is concerned with LC allocation issues and consequently freight logistics sector related to important transport routes and corridors. The freight logistics sector implies all processes, which are needed to supply industry, retail and wholesale

and the end customer with goods (Meyer-Rühle, et al. 2008). The second objective is to explore the integration of Information and Communication Technologies (ICT) and operability of LC in order to point out how modern technologies improve logistics operations, including management, monitoring and forecasting. The focus is mostly sited on Geographic Information System (GIS), Global Positioning System (GPS), and Radio Frequency Identification (RFID). All of these technologies have exactly defined role in the process of recording data in material and information flows. Moreover, this paper proposes the integration of these technologies which facilitates decision making process and enables many benefits.

The paper is organized as follows. The second Section provides a brief review of strategies and opportunities of LC deployment in Serbia. The third Section describes LC allocation scenarios and framework with a particular focus on some new allocation strategies. The fourth Section shows review of ICT applications and propose integrated Logistics Centres Database (LCD) system. The final remarks and conclusion are in the last Section.

## **2. REVIEW OF STRATEGIES AND BENEFITS OF THE LC ALLOCATION**

Serbia belongs to a small group of European countries which do not have defined and developed network of LCs nor established strategy for integration and application of ICT technologies in logistics sector. Possibility to reduce the transportation duration and Serbian favorable geographical position provide an opportunity to reorganize and improve current economic situation and enable progress of the country. Therefore, establishing the LC allocation framework and its practical application has been imposed as a priority. Strategies concerning LC allocation were proposed several times in the past:

1. "Social agreement on the development of integral transport" – Federal Government "SFRJ", from 1985.
2. "The network of logistics centres in Serbia and SFRJ", from 1986.
3. "Regional and spatial plan of the Republic of Serbia", from 1996.
4. "Economic development strategy in Serbia until 2010.", from 1996.
5. Project "IMOD X – Facilitating Intermodal Transport in Serbia", from 2006.
6. "Regional and spatial plan of the Republic of Serbia until 2021.", from 2010.
7. "Regional and spatial plan of the Autonomous Province of Vojvodina until 2020.", from 2011.

Unfortunately, practical implementation of these strategies has always been omitted (except in the latest three which are still active) because of the various phases through which Serbia passed in recent history. Only fractions of strategies were implemented and realized, and as a result full-scale effects and benefits were always omitted. When defining a LC framework it is necessary to thoroughly elaborate the most important features inside an LC (warehouses and intermodal terminals) as well as basic services (custom district, post office, public telephones, bus services, parking areas and loading/unloading operations, restaurants, filling station, etc.) which are normally found with a LC (Europlatforms EEIG, 2004). Those elements have not been analyzed in previous studies.

Generally, the LC concept is based on three important elements (Europlatforms EEIG, 2004):

1. Territorial planning alongside infrastructure rationalization;
2. Transport quality;
3. Intermodality development.

Framework formulation concerning logistics concept and LC allocation will affect by increasing awareness concerning logistics importance and potential multiple benefits:

- Greater investments flows;
- Higher employment rate;

- Improvement of the economy in all regions;
- Favorable conditions for the regional development;
- Implementation of modern ICT technologies;
- Improved regional supply chains and distribution system, as whole;
- Enhancement of road infrastructure;
- Reduction in transport costs;
- Environmental protection;
- Redirection and attraction of the regional goods flows.

### 3. LC ALLOCATION SCENARIOS AND FRAMEWORK

Measures, solutions and priorities of development of logistics and intermodal transportation in the economic system in Serbia are linked to increasing market competitiveness of the economy and infrastructure and logistics networks and centres (Tadić and Zečević, 2012). Development of the LC strategy provides the opportunity for establishing a platform for further analysis. The main objectives are to unambiguously define phase sequence when implementation phase occurs, improve the quality of logistics services and reduce logistics costs. Currently, LC allocation in Serbia is the most concrete elaborated in project "IMOD X - Facilitating Intermodal Transport in Serbia", while LC allocation in Autonomous Province Vojvodina (APV) is based on strategy "Regional and spatial plan of the APV until 2020".

#### 3.1. Scenarios of the LC deployment in Serbia

The project "IMOD X - Facilitating Intermodal Transport in Serbia" proposes three scenarios for the LC allocation. The first scenario involves establishment of core network of LCs with a minimal number of terminals. The second scenario implies enlargement of the basic core network in accordance with Corridors VII and X, while the third scenario suggests expansion of second proposal to the whole country. These three defined scenarios propose successive investment in logistics sector in phases, which is a very good strategy, but it is necessary to take an additional factor into consideration – construction of the Corridor XI. Two supplemented scenarios have been proposed in this paper.

**The first** scenario is called "*Scenario Pillar*". The main idea was to point out the most developed cities – as regional pillars and consequently propose them for potential location of LC. Based on market analysis and regional development the following cities are proposed as pillars: Subotica, Novi Sad, Beograd, Kragujevac and Niš (Figure 1). All LCs are placed near three Corridors, and considering current economic situation proposed number of LCs is sufficient at the moment.

**The second** scenario is called "*Scenario Corridors*". The basic difference between this scenario and the existing one in the project "IMOD X – Facilitating Intermodal Transport in Serbia" is in additional factor – Corridor XI. Corridor XI should be constructed by 2016, according to the Civil Engineering of Ministry Department. Proposed network of LCs is larger for 3 additional LCs compared to the previous version (Figure 2). This scenario may be appropriate in the future when Serbia becomes strong logistics factor in the region.

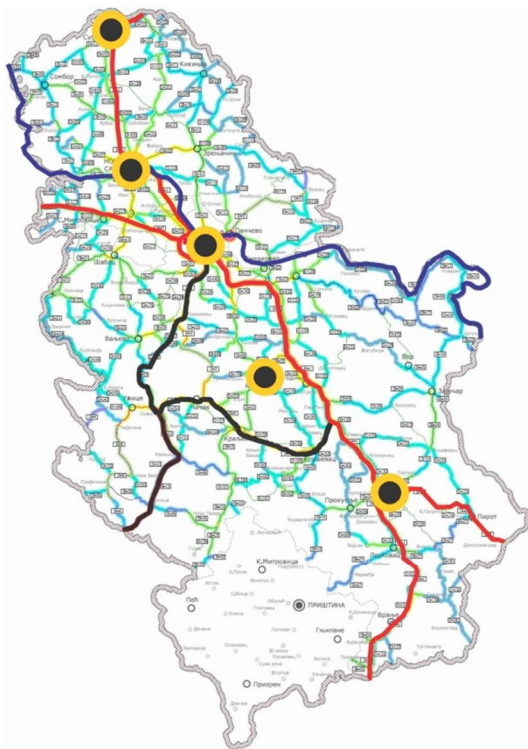


Figure 1 Illustration of the "Scenario Pillar"

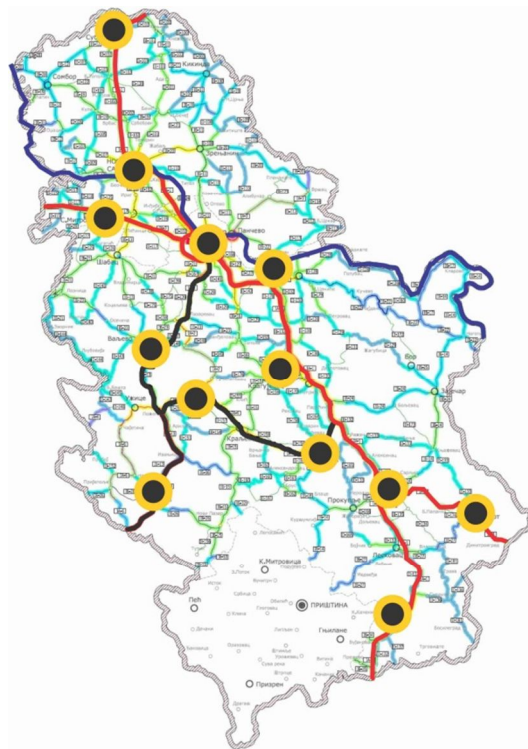


Figure 2 Illustration of the "Scenario Corridors"

### 3.2. Scenarios of the LC deployment in APV

Considering that APV is the most developed region in Serbia, a special attention is dedicated to the LC allocation. In accordance with the latest strategy "Regional and spatial plan of the APV until 2020", one scenario of LC allocation is proposed. Strategy proposes the ranking of LC significance at four levels:

1. The first level – LC of international importance (Novi Sad, Pančevo, Apatin-Sombor and Bogojevo);
2. The second level – LC of regional importance (Zrenjanin-Kikinda and Sremska Mitrovica);
3. The third level – LC of national importance (Subotica, Bečej-Novi Bečej and Vrbas);
4. The fourth level – LC of regional frontier zone (Novi Kneževac-Kanjiža-Senta-Rabe, Vršac-Bela Crkva and Bačka Palanka) (Figure 3).

As opposed to this strategy Figure 4 proposes smaller number of LCs based on estimated current needs.

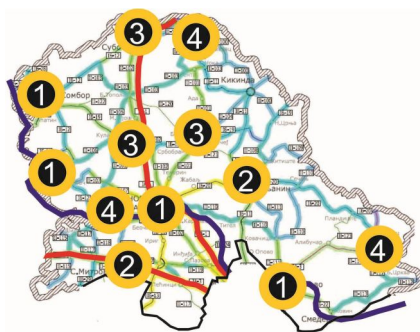


Figure 3 The current LC strategy

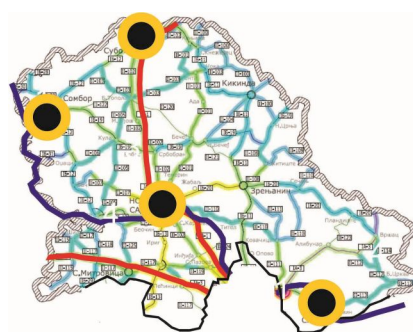


Figure 4 Proposed LC strategy

Figure 3 shows very wide network of LC. This strategy implies a high economic development of a region and maximum capacity utilization. Considering that a deadline for the strategy realization is 2020, a very short period is imposed for such an opportunistic country development. Figure 4 shows more realistic scenario.

### **3.3. Logistics cluster scenario**

Important viewpoint of LC allocation is a proposal of cluster scenario. Logistics clusters are an agglomeration of three types of corporate activities (Tantsuyev, 2012):

1. Firms providing logistics services (3PLs, transportation, warehousing and forwarders, etc.);
2. Logistics operations of industrial firms, such as the distribution operations of retailers, manufacturers and distributors;
3. Operations of companies for which logistics is a significant part of their business.

Several models of modern logistics clusters which are implemented in the USA are analyzed (Arntzen, 2012): Major Seaport, Auxiliary Seaport, Major Inland, Auxiliary Inland and Inland Air. Only Inland Air strategy can be applied in Serbia because every other strategy requires Seaport and may be applied only in interstate cooperation. The main potential of such integration lies in Serbian association to the European Union (EU). If implementing Inland Air strategy the main Hub should be located in Belgrade. Airplanes, trains and trucks are the main transportation means in this scenario. This solution may be even better proposal compared to the wide LC network allocation. Nevertheless, further analysis should be carried out, because this kind of proposal hasn't been considered, so far.

## **4. ICT INTEGRATION AND APPLICATIONS IMPROVING LC OPERABILITY**

### **4.1. Review of ICT application**

This section focuses on two types of ICT technologies (RFID and GPS) and GIS methodology. Each approach has its particular role in improving LC operability.

Radio Frequency IDentification (RFID) is one of the most promising, rapidly developing and easy-to-use technologies, which uses radio-frequency (RF) signals for automatic identification of objects and items. Compared to the old systems, the system using the RFID sensor network architecture is able to provide complete information for LC resource management while the cost, complexity and time required for such a system implementation were significantly reduced as a result of the simple and flexible network architecture (Yang, et al. 2010). The use of RFID has several benefits in a supply chain including efficient terminal operations, and the use of cross-docking method in LC (Eckhardt and Rantala, 2012). RFID also increases effectiveness of organization's daily operations in warehouse, defining it as intelligent system (Ilin and Simić, 2012). In addition, the system can easily be removed and re-implemented in the event of a possible emergency relocation of the LC (Yang, et al. 2010).

The Global Positioning System (GPS) is the most promising technology used for acquiring position of information in outdoor environments (Prasanna and Hemalatha, 2011). GPS has an important role in controlling material flows between LC and other facilities (e.g. other LCs, enterprises or warehouses). It is especially emphasized in GPS tracking. The timing of deliveries and pickups is critical to the profitable operation of the company. To ensure this, GPS tracking and logistics are integrated, making logistics system more efficient. The installation of GPS technology ensures that the delivery of the materials will be made at a certain time. When the minimum level is reached, the logistics company knows that the needed material is on a specific truck and where that truck is (Ilin and Simić, 2012).

A Geographic Information System (GIS) is a computer-based software tool that facilitates the mapping and analysis of information within a geographical area (Rossetti et al. 2008). GIS provides competitive advantage in marketing and planning for companies on the supply side of logistics (Forster, 2000). Key strategic decisions pertaining to any logistics network configuration include: determining the optimal number of LC, determining the location of each LC, determining the size of each LC, allocating space for products in each LC, determining which products need to be transported, and in what quantities, determining the best routes for a vehicle in a transportation network (Snow, 2012).

#### 4.2. Integrated LCD system and potential benefits

RFID and GPS technologies and GIS methodology can be integrated in several ways (Li et al., 2008). This approach aims to propose creation of one centralized comprehensive information management system – Logistic Centres Database (LCD) system. LCD presents a new, original way to explore, analyze, share, and synthesize grouped data and provides multiple benefits. Figure 5 shows LCD system with all components. The main idea was to propose:

1. Data collection concerning stock levels from all LC in the region or country;
2. Data collection concerning vehicles routings and consequently material flows directing;
3. Software platform creation based on GIS.

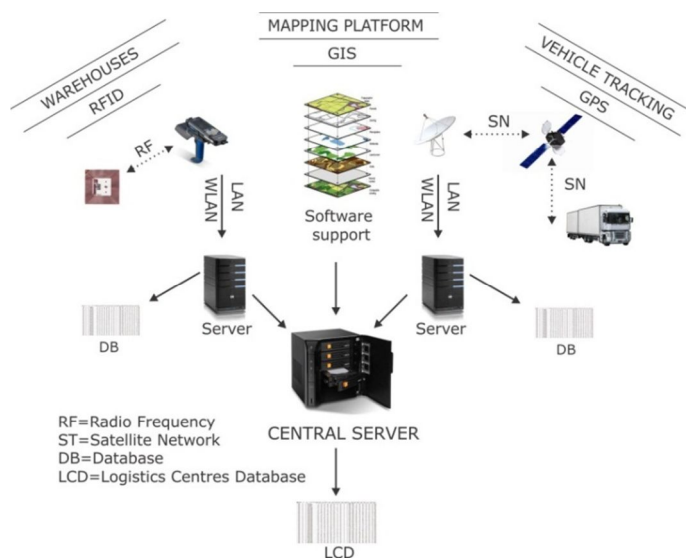


Figure 5 – Illustration of an LCD system

The final output of an LCD approach is constantly updated database based on GIS. At first, the complete insight regarding material flows, stock levels, delivery deadlines and lead times will be obtained and centralized. Furthermore, several additional opportunities will be enabled, including management, monitoring and forecasting. Queries in LCD should be projected to provide rapid and precise answers which improves and accelerates decision-making process, thus, enhancing the effectiveness and efficiency of the system management. Also, an LCD system is conceived with the purpose to improve solving of potential problems in the LC network. The concept of LCD system implicates variable data, semi-variable data and invariable data (Table 1). Variable data should be updated constantly (at daily base or even more often). Semi-variable data should be monitored periodically, and updated when changes in LC network occur. Invariable data are usually fixed and they are not changing except in the case of natural disasters or some other contingencies.

Table 1 An LCD system with highlighted data types



LCD	<i>Variable data</i>	RFID	Stock levels in all LCs;
		Analysis	Market forecasting and redirection of material flows;
	<i>Semi-variable data</i>	GPS	Vehicle tracking data between LC and all other entities;
		Analysis	Shifting secondary facilities;
	<i>Invariable data</i>	GIS	Location of Corridors and roads;
		Analysis	Location of LC;

LCD presents a new way to explore, analyze, share, and synthesize data. Moreover, the system provides many benefits:

- Traditional method of organization and storage data on the paper is in the past;
- All relevant data concerning LC and material flows are stored in one location and very easily updated;
- A large amount of data can be stored and organized;
- Simultaneous accesses;
- Visualization of highlighted processes;
- Relation between database and map is interactive, which means that when database is updated changes become visible on the map;
- Multilayer map based on GIS (e.g. LC layer, external warehouses layer, manufacturer layer, consumer layer, etc.) enables different spatial analyses. This option can be very useful when expanding LC network;
- Decision making process regarding some issues is improved and enhanced (e.g. road traffic congestion prediction and consequently redirection of material flows);
- Conceptual analyses (e.g. assessment of emission and environmental impact, transportation modeling, variation in stocks);
- Planning and prediction of potential changes and constraints in the LC network;
- Network modeling;
- System modeling;
- Upgrading option with similar ICT technologies and databases.

ICT logistics integration and application is a complex project which requires reorganization of technology, processes and people. ICT adoption may bring many difficulties and obstacles: lack of trust concerning reliance on information systems, incompatibility with existing systems, high price, fear of supply chain collapse, insufficient number of qualified personnel, doubts concerning security, etc.

## 6. FINAL REMARKS AND CONCLUSION

LC allocation strategies provide an opportunity for unambiguous definition of a level of logistics development in Serbia currently. Research framework indicates that if the planned strategies become applicable, logistics in Serbia will prosper. However, two mentioned strategies (for Serbia and for APV) need to be more in accordance with each other. Also, unavoidable topics are environmental issues. Logistics establishment and blooming bring organizational, economic and financial benefits for Serbia and the whole region, but they also have negative effects because of increasing pollution. Moreover, the most vehicle fleets in Serbia have diesel engines which highlight another important factor – noise. There are many contemporary solutions for noise reduction, especially along the highways and corridors. Additional study regarding these questions should be carried out.

Future research should be extended to reforming the current LC strategy and the expansion of ICT solutions and opportunities. Firstly, proposed LC strategy needs to be additionally explored regarding highly variable markets environments. Additionally, new customer' requirements are constantly arising and therefore logistics strategy needs to be frequently updated and adjusted. Secondly, there are many additional ICT solutions

which can further enhance and improve LC operability (e.g. internet, wireless communication, laser technologies, electronic data interchange, etc.).

## **ACKNOWLEDGMENT**

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# GLOBAL SUPPLY CHAIN DESIGN: UNDERSTANDING COSTS THROUGH DYNAMIC MODELLING

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## ABSTRACT

We study the economics of the outsourcing decision from a supply chain dynamics perspective. Production can be either in the UK, where products are delivered on trucks to a UK warehouse, or in China where product is shipped via a container liner to a UK warehouse. We show that the traditional "landed cost" approach of purchase price plus transport costs overestimates the benefit from outsourcing products to China. However, the dynamic costs associated with the pipeline inventory, the UK inventory & the UK warehousing capacity costs associated with unloading the containers is not large enough to change the outsourcing decision.

*Key words:* Outsourcing, globalisation, Order-up-to policy, inventory & capacity costs.

## INTRODUCTION

Industrialisation of less developed countries, the emergence of new markets & improvements in transportation are increasing the options for sourcing & supply chain design. Supply chain costs are, to a large degree, determined by the structure of the supply network, & dynamic (bullwhip related) costs tend to increase with distance & lead time. Supply chain modelling can be used to understand the cost behaviour of alternative network designs, & to help choose the best solution. However, it can be difficult to decide which variables to model & which approaches to employ? Sophisticated models can help to explain the trade-offs, but may be too complex to communicate insights to key decision makers. Simple models can be persuasive, but there is a risk that key variables may be overlooked, leading to sub-optimal solutions. These dilemmas are explored via two overseas outsourcing case studies for double beds & a sample of 4 high-tech industrial products, using real data for demand processes, manufacturing cost, weight, volume, & associated transportation costs. The products have been chosen to explore the impact of different value densities (£ per Kg) on cost behaviour & model efficacy, where beds represent low value density & with the industrial products ranging from medium, high, very high to super value densities.

## REVIEW OF SELECTED LITERATURE

A review of academic literature in the field of supply chain design reveals three possible supply chain modelling & design methodologies, which may be broadly classified as: *deterministic*, where a constant or average demand (e.g. Cohen & Lee, 1989) is assumed (as in Linear Programming based approaches employed in most commercially available software); *stochastic*, where probability density functions are employed to represent uncertainty (e.g. Lee & Billington, 1993); & *dynamic*, where demand & other variables are modelled evolving over time & particular attention is given to feedback loops, (e.g. Forrester, 1961 & Berry & Towill, 1995). In practice, both stochastic & dynamic approaches are employed once the physical supply network has been decided. *Dynamic* supply chain design employs control theory to understand the effect of time delays & feedback paths on system behaviour. However, as both stochastic & dynamic approaches are normally applied *after* the physical network has been decided, the potential of these methods is constrained. Ratanachote & Disney (2008) have developed a modelling technique which incorporates stochastic & dynamic analysis to model the

inventory & capacity variances & costs associated with alternative network designs. Dynamic analysis adds some complexity to the modelling procedure, & it would be useful to develop some criteria to help identify the circumstances in which it should be applied. Supply chain scenarios are inherently complex & there are many different variables that can be incorporated into a model. However, if too many variables are considered the model becomes unwieldy & difficult to communicate to managers. If the model is too simple, then key insights can be missed. According to Pidd (2006) in any modelling exercise it is important to ensure that a valuable result is delivered without being dragged into too much detail. Selecting which variables to model & which techniques to employ is therefore a critical decision.

Supply chain segmentation reveals a similar problem. According to Fuller et al. (1993) many companies attempt to deliver dissimilar products through the same supply pipeline with sub-optimal results, arguing instead for *logistically distinct pipelines*. This concept now appears in the literature as 'supply chain segmentation' (Lovell et al., 2005) & 'value stream classification' (Christopher et al., 2008) & is closely related to supply chain design, as pipelines must be designed for groups of 'similar' products. However, there are many different criteria by which a company's products can potentially be grouped, including: stage in lifecycle, handling characteristics, shelf life, physical size & weight, value, demand location, demand level, demand variability, service expectations, lead time, transport mode availability & customs duties. Just as supply chain modellers must decide which variables to model, supply chain analysts must choose the most appropriate bases for segmentation. In both cases, it is necessary to choose the variables which exert the biggest influence on supply chain performance, either for the purposes of effective modelling or optimal pipeline design.

Lovell et al. identify the key segmentation variables as demand variability, throughput (volume) & product value density, exploring their impact on pipeline design choices, including transportation mode (speed) & degree of inventory centralisation. In relation to the supply chain modelling dilemma, the authors developed an initial view that product value density should guide the choice of modelling technique (McCullen & Disney, 2008), as high product value density would be associated costly pipeline inventories. This leads to our *Hypothesis*: Where product value density (PVD) is high, pipeline inventory & bullwhip costs are dominant, & dynamic-stochastic modelling is appropriate. Where product value density is low, transportation costs are dominant, & static modelling is 'good enough' to select an optimal solution.

Two case studies are employed to explore the hypothesis. Case Study 1 involves an outsourcing decision for a furniture manufacturer (a low value density scenario). Case Study 2 involves the same outsourcing scenario, but considering high tech industrial products (a high value density scenario). Both cases are analysed using dynamic-stochastic modelling, with both static & dynamic costs separately identified. The two cases are compared & the efficacy of dynamic-stochastic modelling discussed in relation to the hypothesis.

## **THE SUPPLY CHAIN SCENARIOS**

In both cases, UK or outsourced Chinese manufacture are compared. Both case studies employ the same supply chain scenarios. For UK manufacture, products are delivered directly to a warehouse, unloaded & 'put away', with the company incurring 2 weeks of pipeline cost, unloading cost & inventory cost. In the case of Chinese manufacture, the

factory gate product costs are substantially lower, but goods must be paid for before they leave the factory, & the company incurs 8 weeks of lead-time with the associated pipeline cost, unloading cost & inventory cost. When shipping from China, high cube 40ft containers are used for the beds as they are relatively lightweight & volume constrained. For the industrial products, a normal 40ft container is used as they are payload rather than volume constrained.

The demand  $d$  in week  $t$  in all cases was deemed to follow an AR(1) model,

$$a_t = \phi(a_{t-1}) + \varepsilon_t, \quad d_t = a_t + \mu_d, \quad (1)$$

where  $\varepsilon_t$  is a normally distributed, i.i.d. random process with a mean of zero & a standard deviation which we matched to the real-life demand pattern. The mean demand  $\mu_d$  & the auto-regressive parameter of  $-1 < \phi < 1$  were also matched to the real life demand pattern, see Table 1 for numerical values. Product value densities (PVD), on the basis of UK manufactured costs, are also shown in terms of cube & weight. The AR(1) demand process has a variance of

$$\sigma_{AR}^2 = \sigma_\varepsilon^2 / (1 - \phi^2). \quad (1.2)$$

The companies employed an 'order-up-to' (periodic review) replenishment system which involves regular shipments & variable order quantities. The order-up-to policy requires two forecasts. One of these forecasts is the demand over the lead-time. The other is a forecast of demand in the period after the lead-time. We use conditional expectation to create these forecasts (details omitted for brevity, but details can be found in Hosoda and Disney (2006)). It then follows that the variance of the replenishment order placed on the Chinese supplier or UK factory is given by,

$$\sigma_O^2 = \sigma_\varepsilon^2 (1 + \phi + 2\phi^{4+2T_p} - 2\phi^{2+T_p}(1 + \phi)) / ((\phi - 1)^2 (1 + \phi)), \quad (3)$$

where  $T_p$  is the replenishment lead-time,  $T_p = 8$  for China supply,  $T_p = 2$  for UK supply. The inventory variance (Disney & Hosoda, 2006) is likewise given by

$$\sigma_{NS}^2 = \sigma_\varepsilon^2 (\phi^{4+2T_p} - 1 + 2\phi(1 + \phi) - 2\phi^{2+T_p}(1 + \phi) + T_p(\phi^2 - 1)) / (\phi - 1)^3 (1 + \phi). \quad (4)$$

The order & inventory variances produce dynamic costs in supply chains. The inventory variance creates a need to hold inventory in the UK warehouse. The ordering variance creates a

Case	Product	Mean demand $\mu_d$	Standard deviation $\sigma_\varepsilon$	Autoregressive co-efficient $\phi$	PVD (£/m <sup>3</sup> )	PVD (£/Kg)
Beds 4 You	Double beds	5400	250	0.7	141.36	1.50
Industrial Products	IP1	32	13.53	0.242	1,7122.62	26.02
	IP2	26	12.9	-0.02	25,103.54	68.28
	IP3	8	10.64	0.258	38,879.49	120.66
	IP4	14	14.46	-0.17	339,439.05	284.08

Table 1. Characteristics of the demand process & PVD

variable workload in the UK warehouse associated with unloading the products & putting it away. There is also a cost associated with the inventory owned in the pipeline. We will now briefly describe how each cost is calculated.

### Inventory costs

Inventory costs are driven by the value of the inventory, the interest rate charged, the standard deviation of the inventory levels & the service level (availability) required. We

will assume that inventory holding & shortage costs exist & can be described in the time domain by

$$\text{Inventory cost for period } t = H [ns_t]^+ + B [-ns_t]^+ . \quad (5)$$

Here  $ns$  is the net stock at the UK warehouse at time  $t$ .  $[x]^+$  is the maximum operator, that is,  $[x]^+ = x$  if  $x > 0$ , otherwise  $[x]^+ = 0$ .  $H$  is a holding cost per unit per week &  $B$  is a backlog cost per unit per week. The inventory holding cost is set to be equal to the unit cost plus freight charges, pipeline inventory costs, & unloading costs, all multiplied by the weekly interest rate, 0.5%. The backlog cost is set to ensure the 95% of weeks end in a positive inventory (to meet the target inventory availability target).

Both companies offer products for immediate collection & delivery. They both target 95% inventory availability. The cost of holding an item in inventory for one week,  $H$ , can be obtained by multiplying the product's cost by the cost of capital (0.5% per week). The backlog costs are obtained using (6) that ensures that 95% availability also minimises the expected per period inventory cost,

$$B = \frac{H \times 0.95}{1 - 0.95} . \quad (6)$$

In order to ensure the sum of the expected inventory holding & backlog costs is minimised then the Target Net Stock ( $TNS^*$ ), the safety stock at the UK warehouse, needs to be set to (7). We can see that it is a linear function of the standard deviation of the net stock levels. This is safety stock level can be obtained via standard newsvendor techniques.

$$TNS^* = \sigma_{NS} \sqrt{2} \left( \text{erf}^{-1} \left[ \frac{B-H}{B+H} \right] \right) \quad (7)$$

The average amount of inventory held at any moment of time is  $TNS^* + \mu_d / 2$  & the expected costs associated with the safety stock is given by,

$$I_f = \sigma_{NS} (B + H) e^{-\left( \frac{B-H}{B+H} \right)^2} / \sqrt{2\pi} . \quad (8)$$

### Capacity costs

The supply chain lead-time & demand process also create a capacity cost in the UK warehouse. Specifically it is associated with the order variance & it creates a variable workload in the warehouse associated with unloading products from trucks & putting them away in the warehouse. UK staff, in both cases, are guaranteed a standard (40 hour) working week & offered overtime at "time & a half" during evenings & weekends. These "unloading & putting away" capacity costs are given (Disney et al., 2012) by

$$\text{Unloading (labour) cost for week } t = U (S + \mu_d) + W \left[ o_{t-Tp-1} - (S + \mu_d) \right]^+ , \quad (9)$$

Note that, here we are ignoring the fact that labour could be used to manage other products in the warehouse. So the capacity costs should be taken to be a worst case scenario. Thus the following unload cost function exists.  $U$  is the cost of unloading a bed.  $W$  is the cost of over-time work per bed per week,  $W = 1.5 \times U$ .  $o_{t-Tp-1}$  is the order placed in week  $t-Tp-1$ ,  $\mu_d$  is the mean demand &  $S$  is the slack labour capacity above (or below when  $S$  is negative) the mean demand. Thus  $S + \mu_d$  is the unloading capacity of the normal working week. The optimal slack capacity is given by

$$S^* = \sqrt{2} \sigma_o \text{erf}^{-1} \left[ \frac{W-2U}{W} \right] , \quad (10)$$

and the minimised unloading & putting away cost in the UK warehouse is given by

$$C_f = U \mu_d + \left( e^{-\left( \text{erf}^{-1} \left[ \frac{W-2U}{W} \right] \right)^2} W \sigma_o \right) / \sqrt{2\pi} . \quad (11)$$

## Pipeline costs

Many Chinese factories require goods to be paid for before they leave the factory, Beds For You have 8 weeks of inventory in the supply pipeline that has to be financed in the Chinese option. There is often no similar cost for the UK accounts, as goods are paid for when they are delivered. The expected number of products in the pipeline can be easily obtained via Little's law,  $T_p \times \mu_d$ .

### CASE STUDY 1: THE BEDS FOR YOU SCENARIO

A UK supplier of double beds charges £30 per bed. The UK supplier incurs costs of £6 for materials & energy, £21 for labour & £3 for other costs & profit. It is delivered free to the Beds For You warehouse in on pallets. The cost of unloading the truck with warehouse truck is £0.25 per bed in normal working hours (£0.375 in over-time). An order that is placed in one week, will arrive in the week after next, thus the physical lead-time is one week with a review period of one week.

The Chinese supplier of double beds charges £9 per bed. Beds For You suspects that the Chinese supplier incurs costs of £5 for materials & energy, £3 for labour & £1 for other costs & profit. It is delivered FOB in a 40ft High Cube container to a Cargo Liner that leaves from Shenzhen Port in China for the UK. The container capacity details were shown in Table 1. The Chinese supplier will pack the 40ft High Cube container by hand & they can fit up to 360 double beds into the container, as a cost of £3350 delivered to the UK warehouse. These freight charges are paid for when the product is delivered. The replenishment lead-time is 8 weeks. This is made up of 6 weeks on board the Cargo Liner, one week for the factory to deliver to the port & one week for the shipping company to deliver the container from the UK port to the warehouse.

As the container is not palletized (to put palletized beds in a container would waste too much space) it has to be unloaded manually. The shipping company require a container to be unloaded within 3 hours (or a charge of £50 per hour will be levied). The warehouse manager estimates that it will cost £1.50 per bed to unload the container & palletize the beds at warehouse (3 hrs to unload with 5 people @ £12 per hour per person divided by 360 beds = £1.50) in normal working hours. In over-time working this unloading cost increases to £2.25.

Both static & dynamic elements of cost are analysed to estimate the total cost per bed for both options, to be obtained from the: Unit product cost & freight cost (static); Expected pipeline inventory costs (dynamic); Expected unloading capacity required & unloading costs (dynamic); Inventory costs, consisting of safety stock & cycle stock (dynamic); Total costs (static & dynamic). Let's first consider the obvious costs, the unit "landed" costs. Collecting together the information described above we have Table 3. Therefore the freight charges per bed will be  $15.5 \times 2870 / 5400 = 8.2379 = \text{£}8.24$  per bed. So, at first sight the unit cost of beds from China is only 57.5% of that from the UK supplier.

Dynamic costs will be present because of the differences in the lead-times. We will need to use our knowledge of the order rate & net stock variance amplification ratios (equations (3) & (4)) to calculate the impact of the lead-time, demand, forecasts & replenishment rules on these dynamic costs. We note that both the order & the

inventory variances are much smaller for the UK supply. The inventory related costs are linear in the standard deviation of the net stock levels & this is influenced by the lead-time. The inventory costs are also influenced by the value of the inventory, which is much higher for the UK supply than for the Chinese supply. However, the difference between the two scenarios in terms of inventory related costs is very small compared to the impact of the labour cost. More interesting is the fact that, on the average, 70% more stock has to be held in the Beds For You warehouse with Chinese supply when compared with UK supply. This could have implications for warehouse requirements or product range offering in Beds For You.

## CASE STUDY 2: INDUSTRIAL PRODUCTS (HIGH VALUE DENSITY)

The Industrial Products Company has a UK supplier, & would like to explore the economics of outsourcing to China. Four representative products, from their broad product range, have been chosen for the purposes of comparison. The products are made from CNC machined components & include an electric motor. Materials represent 70% of factory gate costs, & these costs are unaltered by outsourcing to China. The remaining 30% of costs are labour costs, which are 37% lower in China, resulting in an overall 26% reduction in unit purchased costs. Selling prices are considerably higher, & the sales margin includes the contribution to overheads & profit.

The individual products have much lower mean weekly demand than the beds, & containers are filled with a variety of different products. The company uses standard 40ft containers which are packed with a variety of different sized packages, the maximum container utilisation by volume is only 80%. Product size, volume & associated transportation costs are shown in 2 on the basis of a China to UK container shipping cost of £3350. Products IP1, 2 & 4 can be unloaded by hand, & the unloading costs have been estimated on the basis of the average hourly rate, giving normal unloading costs of £0.8, £0.8 & £0.4, with overtime rates at time & a half. Product IP3 is heavy & must be unloaded by fork-lift truck, giving normal unloading cost of £5, & £7.50 in overtime.

Product	Weight (Kg)	Volume (m <sup>3</sup> )	No. per payload	No. for 80% of the payload	Unit freight costs (£)
IP1	30	0.046	886	1188	3.78
IP2	31	0.084	863	647	5.18
IP3	54	0.166	497	326	10.27
IP4	6	0.005	4430	10786	0.76

Table 2. Shipping characteristics for Industrial Products

## NUMERICAL ANALYSIS

We have calculated the following cost comparisons shown in Table 3.

Company	Beds For You		Industrial Products Co.							
Product	Double Bed		IP1		IP2		IP3		IP4	
Country of manufacture	UK	China	UK	China	UK	China	UK	China	UK	China
Unit purchase cost (£)	30.00	9.00	780.50	579.80	2,103.00	1,562.23	6,455.50	4,795.52	1,704.50	1,266.20
Unit freight charges (£)	0	9.62	0.00	3.78	0.00	5.18	0.00	10.27	0.00	0.76
<b>Landed cost</b>	<b>30</b>	<b>17.24</b>	<b>780.</b>	<b>583.5</b>	<b>2103</b>	<b>1567</b>	<b>6455</b>	<b>4805</b>	<b>1704</b>	<b>1267</b>



			50	8						
Percentage change in landed costs		-43%		-25%		-25%		-26%		-26%
Average number of units in pipeline	0	43200	64	256	52	208	16	64	28	112
Value of goods in pipeline (£)	0	388800	49952	148429	109356	324944	103288	306913	47726	141814
Cost of pipeline inventory per week (£)	0	1944	250	742	547	1625	516	1535	239	709
<b>Pipeline cost per unit (£)</b>	<b>0.00</b>	<b>0.36</b>	<b>7.81</b>	<b>23.19</b>	<b>21.0</b>	<b>62.5</b>	<b>64.6</b>	<b>191</b>	<b>17.0</b>	<b>50.65</b>
Normal unloading costs, $U$	0.25	1.5	0.8	0.8	0.8	0.8	5	5	0.4	0.4
Overtime unloading costs, $W$	0.375	2.25	1.2	1.2	1.2	1.2	7.5	7.5	0.6	0.6
Order standard deviation, $\sigma_o$	561	810	17.79	17.85	12.65	12.65	14.28	14.34	12.35	12.36
Slack capacity at warehouse, $S^*$	-241	-349	-7.66	-7.69	-5.45	-5.45	-6.15	-6.18	-5.32	-5.32
Weekly capacity required, $S^* + \mu_d$	5159	5051	24.34	24.31	20.55	20.55	1.85	1.82	8.68	8.68
Unloading (labour) costs per week, $C$	1426.43	8762.54	33.36	33.39	26.32	26.32	78.93	79.10	8.29	8.30
<b>Unit unloading cost</b>	<b>0.26</b>	<b>1.62</b>	<b>1.04</b>	<b>1.04</b>	<b>1.01</b>	<b>1.01</b>	<b>9.87</b>	<b>9.89</b>	<b>0.59</b>	<b>0.59</b>
Percentage change in unloading costs		514%		0%		0%		0%		0%
Net stock standard deviation, $\sigma_{NS}$	493	1951	27.84	51.81	22.05	38.02	22.16	41.50	22.53	37.73
Unit cost	30.26	20.60	789	608	2125	1631	6530	5007	1722	1318
Inventory holding cost, $H$	0.15	0.01	3.95	3.04	10.63	8.15	32.65	25.04	8.61	6.59
Backlog costs, $B$	2.88	0.20	75	58	202	155	620	476	164	125
Safety stock at warehouse, $TNS$	811	3209	46	85	36	63	36	68	37	62
Average stock	3511	5909	62	101	49	76	40	72	44	69

in warehouse, $TNS+\mu/2$										
Inventory costs per week, $I$	154	41.45	227	325	483	640	1492	2143	400	513
<b>Inventory cost per unit</b>	<b>0.03</b>	<b>0.01</b>	<b>7.08</b>	<b>10.15</b>	<b>18.6</b>	<b>24.6</b>	<b>187</b>	<b>268</b>	<b>29</b>	<b>37</b>
Percentage change in inventory costs		-75%		43%		32%		44%		28%
Weekly landed costs	162000	93096	24976	18675	54678	40753	51644	38446	23863	17737
Weekly pipeline costs	0	1944	250	742	547	1625	516	1535	239	709
Weekly unloading costs	1426	8763	33.36	33.39	26.32	26.32	78.93	79.10	8.29	8.30
Weekly inventory costs	154	41.45	227	325	483	640	1492	2143	400	513
Total weekly costs	163580	111,296	25486	19775	55734	43043	53732	42203	24510	18968
<b>Total cost per unit</b>	<b>30.29</b>	<b>20.6</b>	<b>796</b>	<b>618</b>	<b>2143</b>	<b>1655</b>	<b>6716</b>	<b>5275</b>	<b>1751</b>	<b>1355</b>
Percentage change		-32%		-22%		-23%		-21%		-23%

Table 3. Cost comparison of outsourcing to China

The 'landed cost comparison' arises from a static analysis of purchase cost & transportation cost. The greatest reduction of 43% is achieved for the beds, due to their higher labour content & local material cost savings. When dynamic costs are taken into account, the overall cost reduction is 32%. The largest component of dynamic cost is the unloading cost, which affected by bullwhip-induced under & over-utilisation of capacity. Inventory costs are negligible, as may be expected for such a low value density product. Here we can see that because the unit cost of unloading & palletizing the container manually, the warehouse unloading costs are quite high for Chinese supply option. But we can see that we need more unloading capacity, (above the average demand) for the UK option. This is because the unit of measurement is in number of beds. However, as with the inventory analysis, these unloading costs are rather small in comparison with the other unit costs.

For the industrial products, average landed cost savings of 25.5% are reduced to an average of 22% as a result of dynamic costs, & in these cases the pipeline & warehouse inventory costs are absorbing around 3% of the saving, with negligible unloading costs, as may be expected for these higher value density products. A better understanding of the overall cost composition could be obtained by analysing the percentage of total unit costs for all five products when outsourced.

## CONCLUSION

On the basis of the five products analysed, the hypothesis is unsupported. However, significant differences in product handling characteristics & demand processes are also driving the dynamic element. The relatively high unloading cost for the beds is driving

the dynamic costs, &, at nearly 10%, suggests than dynamic analysis *is* worthwhile even for this low PVD product. For the industrial products, it is useful to know that some 3% of total cost arises due to the bullwhip effects on inventory.

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## **THE USE OF LIVING LABS FOR DEVELOPING IOT SERVICES FOR THE LOGISTICS IN FOOD SUPPLY CHAINS**

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### **ABSTRACT**

Food cold chains underlay specific legal restrictions, and a seamless traceability of the food from supplier until consumer is required. The use of ICT can provide this traceability, and new concepts like that of IoT can optimise the supply chain in a more efficient way. However, this requires fundamental changes in the supply chain as well as access to customised services. The service development of relevant IoT services is challenging and requires a tight relation between all stakeholders. This paper reports on the first results of using Living Lab and co-creative design methods for service discovery.

### **INTRODUCTION**

In order to ensure the safety and security of their citizens all perishable products to be sold in the common market are subject to strict regulations and laws (Vedovato et al. 2011, UNECE, 2013, Smith and Sparks, 2004). In the area of cold chain logistics, relevant regulations are EU regulation nr.178/2002 which regulates the re-traceability of food throughout the supply chain and gives certain rights to the end customer as well as the Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be Used for such Carriage (ATP) that regulates the temperature range. A lack of traceability comprises high financial risks for those who brought the perishable food on the open market, since these may be subject to claims (Gorny, 2003). To guarantee the traceability a seamless information flow is vital, but still a challenge in complex chains (Arnold, 2008). In order to increase the transparency and to reduce the impact of any disruption in the cold chain, ICT solutions have been introduced at different levels. Today, it is common to use RFID technology (Aung and Chang, 2010, Jedermann, 2009), however these are often just used in part of the supply chain and there are only few examples of seamless use. Reasons for this are the lack of acceptance, as well as heterogenic systems (Arndt, 2006, Meyer, 2007, L4L 2012). An increase use of more complex systems can be observed, comprising not only RFID but also ubiquitous computing as well as communication and sensor networks. In combination these technologies ensures more intelligent systems (Scholz-Reiter, 2005, Windt, 2006) aiming at improving the transparency and data density. In the most advanced cases such an item needs to be able to process and execute decision autonomously (Böse and Windt, 2007). These systems are often known as IoT (CERP-IoT, 2009), Intelligent Cargo (EURIDICE, 2009), or autonomous logistics (Windt, 2006).

These concepts foresee the implementation of RFID and sensors, other basic technological components needed for the realization of intelligent item/cargo are service oriented architectures (SOA) and interoperability platforms for data interchange and collaboration between business partners' mobile technologies and global positioning systems (Schumacher, 2011, Baalsrud Hauge, 2011), consequently such systems lead to

fundamental changes on the involved organisations, and can thus be characterised as a paradigm shift.

## **CHALLENGES**

Especially in complex supply chain networks, where multiple companies and authorities have to collaborate for a successful and efficient processing of cargo, the need for ICT support is not deniable. ICT solutions for supporting the underlying process are widely available today; however, the ability to cooperate and interact with other systems is often very limited.

IoT services based on an open ICT platform for supporting general transport logistics processes in an open architecture can provide a common set of services for supporting the transportation processes from different stakeholders' point of view and thus create a comprehensive view on the processes. In the cold chain, IoT services offer new opportunities for data collection, analysis and actions. For more complex and advanced systems, the provided service can be extended and adapted to fit the actual needs and inter-connect with the existing ERP systems. However, concerning the stakeholders in the supply chain, it is obvious that the different stakeholders have different needs regarding services. Also, if just the transport sector is considered, there are huge differences - both in needs and requirements, but also in the possibilities of investment. Logistic service providers are operating in a low margin sector with high competition. Thus, they are under high pressure from their clients. They form a non-homogeneous group, ranging from micro-size to large companies, with the large variation in the service they offer their customers. This has to be reflected in the service development, since the offered services should support the specific needs, but not unnecessary add-ons causing higher costs. This leads to a challenge - so far most IoT services are developed and offered by ICT service providers. Even though, they know the need of the industry in general, they do not know the individual need of a stakeholder. We see this as one of the main barrier, and thus we have analysed concepts coming from classical product design, in order to include the stakeholder in the development process just from the beginning. A concept that is often used is the one of co-creative design (Hesmer, 2007).

The next section shows a research approach that uses this approach in order to overcome the challenge of developing user specific IoT services.

## **RESEARCH WORK**

The main objective of this work is to explore how new IoT services can be developed using the principle of co-creative design. In a first step, we have however analysed which requirements an IoT system has to fulfil for ensuring the seamless information flow and improved transparency. An IoT service used in the food chain has to be integrated to several backend systems, so that each stakeholder can retrieve the information he needs, and also deliver the information needed by other stakeholders. An example of how such a system can be designed is shown in figure 1. Such a system implemented in a cold chain needs to be scaleable, cargo centric and based on an open platform. The services have to be globally accessible and easy to combine, since the users have different needs. Thus it is important that the IoT services can be easily

combined and ready to apply reducing the integration effort as much as possible (EURIDICE, 2009)

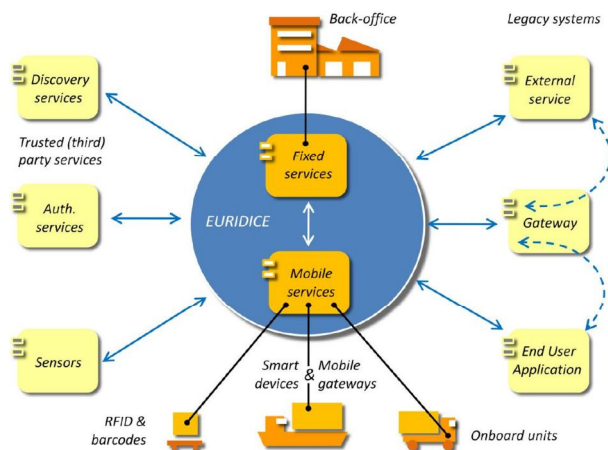


Figure 1: The EURIDICE architecture context (source EURIDICE training, 2012)

Within this system, there are two types of services: the fixed services, deployed at fixed platforms as back-end services to facilitate the end-user applications and the mobile services deployed on mobile devices installed at the cargo containers or vehicles to collect and provide local information, take local decisions and to provide local support for end-user applications in the field. For example, a resulting service could provide feedback to users based on the analysis of real time sensor data. This feedback would be given via different channels, according to the environment or context in the user receives it, i.e. a text message or a visual signal like an emergency light.

Based on existing prototypes and the need for traceability with in a food supply chain, we have defined a set of basic requirements that should be fulfilled:

Name	Functional requirements` description
Temperature monitor	IoT system will record specific cargo conditions (temperature, humidity, weight, etc.) along the transport and log it. Historical data will be visible to relevant actors
Temperature monitor	The IoT system will identify deviations in the trend of the defined cargo conditions and send a warning notification to the user
Position notification	The IoT system will provide the ability to the users to make an automatic (or manual) check of the historical data in any status change
Sealed truck	The IoT system will provide sensors monitoring functionality in order to monitor specific conditions regarding sealed truck
Positioning.	All involved actors will be able to retrieve the cargo position on demand
Alert	Intelligent wagon sends an alert to the user when some of measured conditions values are out of target values.

Battery condition	Intelligent module informs its battery condition if there is a need for maintenance
Warehouse monitoring	The user can specify the conditions to be monitored inside the warehouse
Humidity monitoring	The user will monitor those conditions (real time/on demand).
Deviation warning	In case the weight of the cargo deviates (till complete unloading) from the desired conditions (set by the user) The IoT system will send a notification
Loading verification	The items that are loaded are checked against the predefined plan.
Position alert	When the cargo's position is out of the predefined transportation plan an alert will be sent to the involved actors

In existing systems, even if they are at prototype level, like those of EURIDICE (EURIDICE, 2012) or the Intelligent Container (Lang, 2011) the services needed for the specific pilots are already available, and can of course be reused, but these are partly based on specific sensors and actuators etc. This field is rapidly advancing, and there is a continuously release of new sensors and actuators. Thus, the advances in the technology needs to be considered in the service development process, consequently, adaptable services are needed. This is a complex process, due to the paradigm shift and the fast technological advances; it is difficult for a user to know which possibilities he has, both regarding sensor selection as well as the integration in the operational processes. On the other hand, the service developer does mostly have profound ICT skills, but less competent in understanding the specific user needs and the impact of implementation of the operating processes. In order to overcome the separation of knowledge between the involved stakeholders, the authors looked for usable concepts. Service design has much in common with classical product design, thus it is expected that the same concepts can be used. For a long time user involvement was limited to observation and not active participation (Sanders & Stappers, 2008). However, in order to be able to fit the users' needs in a better and cheaper way, a new way of product development occurred that directly included the involvement of the workers to get access to their experience (Bødker 1996). Also the emerge of new ICT allowing spatial separation of cooperation partner as well as the emerge of a new culture on information sharing and co-operative development imposed by the open software development approach have imposed more user involvement in the design and development process, co-creation takes people's real practices and their quotidian reality into account. Such an environment is often defined as a living lab.

The authors have collected a long experience of both co-creative design as well as being involved in the development of the intelligent cargo concept. Since a few years we have also experimented with service development using creative methods and also by using experimental collaborative working environments. Thus in the first step, a living lab for development of intra-logistic IoT services using an Arduino tool kit was established, as explained in the next section.

## **EXPERIMENTAL SET UP**

This section describes the set up of the experiential working environment. The objective is to collaboratively develop new IoT service solutions which unveil risky situations along a supply chain. In a first step, we looked at intra-logistical issues, with specific risks in forklift-based transport processes, before we extended this to the whole supply chain in a second step.

Thus, in order to foster the development of specific services suitable for food SC, a working environment was introduced in which field experts, technology experts and (end) users can co-create relevant services by using a tool kit. The "co-creation" begins at the early stage of the development process and co-creation is indispensable for this application case as risks in food supply chains are highly dependent of the local logistical processes and the corresponding environment. A significant importance is laid on the communal development based on a practical environment so as to create realistic context information about risk situations and thus compose a fully applicable risk recognition system consisting of different partial functions.

### **Living Labs**

A Living Lab (LL) is an open innovation environment (Følstad, 2008) that uses a variety of methods and tools (Schumacher & Niitamo 2008), as well as supporting exploration of technologies under (almost) real conditions. Participants can co-create services; explore technologies and services; and experiment with them in a safe environment. A successful ideation process is the foundation of every service development, but even though co-creative developed, the successful development of new ideas and resulting services does not ensure that these services meet the needs of the customer at the end. Consequently, the main focus for the discussed LL was the ideation for and exploration of new services. The past experience has shown that the ideation phase is often considered to be the most challenging, and that there is a need of tools supporting the process.

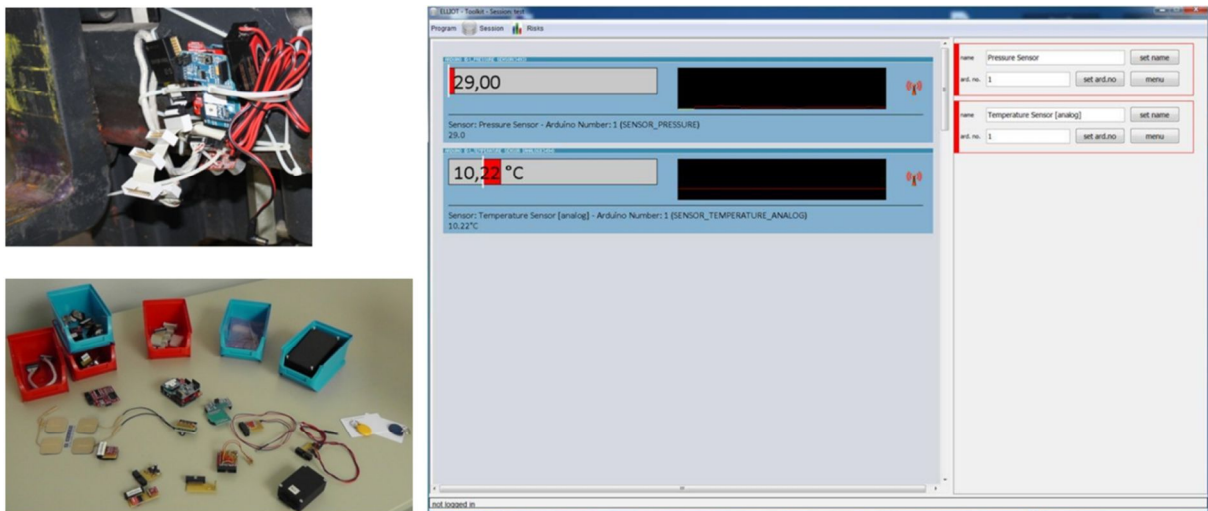
Based upon the collaboration environment, the need of the logistics industry to develop IoT services without specific programming skills and the requirements for an IoT solution in the food supply chain, the following requirements for an IoT platform were derived: (1) a modular approach to attach new and detach old or unneeded sensors easily; (2) an interface which allows observation and configuration by novices (non-experts, field experts; no coding required); (3) ideally an Open Source approach, to provide potential for further adoption at low cost; and (4) a service-oriented architecture for the software.



## IoT Toolkit

For the toolkit Arduino microcontrollers were used. Additionally a graphical user interface (GUI) was developed in order to give novice users the ability to participate in the development work in the living lab.

The microcontroller hardware of the toolkit allows connecting various sensors to a sensor network in individual combinations; besides already available and majorly used sensors like: accelerometer, gyroscope, temperature, humidity, gases, (air) pressure, etc.; more sensors could be prepared to be used by the toolkit. Together with the GUI, these sensors can be configured without coding knowledge. That allows novices and experts to work together on the configuration of the IoT hardware, i.e. the services. In practical terms, this toolkit would *for example* allow configuring a temperature surveillance service for cold chains and as well a cargo based surveillance of location and spatial orientation.



**Figure 2: The IoT Toolkit: Hardware (left) and GUI for sensor overview (right)**

By the use of this toolkit it is believed that the handling of the technology is made easier and that barriers to approach IoT technologies are lowered. However, the toolkit cannot provide industry solutions for immediate implementation.

## Initial living lab workshops

In a first step, we have tested this Living Lab environment with 16 persons, mainly post graduate students but also some young professionals, coming from different fields (logistics, computer science, production and industrial engineering) and then used experts for an assessment of the approach and the services. The workshops had a minimum of five participants and dealt with different scenarios in intra-logistics and long distance transport context. Developed services went through experiments under real conditions and especially one service from valuable goods transport context was followed up by an external feedback collection from field experts. Furthermore, the usability of the toolkit was assessed.

The feedback conducted from field experts on the service for valuable goods transport clearly indicated that the IoT services, which enable a real time assessment and analysis

of sensor data, could heavily improve transport processes, especially for highly sensible goods. Today's usage of offline sensor systems and data logging unities requires time-consuming readouts and data analysis to receive the needed information. An IoT system for real time data assessment and risk surveillance would be a valuable tool and the feedback showed potential demand. However, proof for industrial implementation is still lacking (f.ex. costs vs. increased service quality; i.e. better transparency). The IoT toolkit is able to support the development process of IoT services in collaborative environments and helps to involve all stakeholders.

The feedback is also in line with the requirements for ICT/IoT solutions for supply chains: the real time and seamless information flows, allowing data assessment and according actions on-site is a core asset. However, this also requires integration potential into existing backend solutions. Furthermore, the mentioned real time data flow cannot always be fulfilled since in some areas and regions internet connections are not constantly available; for such parts of the supply chain, the solution should have on board services which allow basic functionality and especially data collection independent from internet access.

### **ANALYSIS AND IMPROVEMENTS OF THE SETUP**

Based on the living lab workshop results, the experiential environment was reconfigured, and we considered how specific creative tools can be included for fostering the ideation of new IoT services among logistics field experts.

Based on the application case, requirements for an IoT solution and the according service-oriented architecture can be derived. The IoT hardware needs to be robust, probably interchangeable and should provide some variety to meet different requirements according to the application environment (different sensors to be used in tropical and humid regions as in Mediterranean regions, etc.). For the design of the SoA two major requirements should be considered: first the ability to provide interfaces for integration into existing SCM/ERP systems; and second the scalability, which plays a key role for the ROI. Solutions should be provided to meet different requirements of the users. While a truck driver might only need a connection to the core system in terms of communication (dispatch messages) and temperature data in order to observe the status of the cargo; wholesalers, producers or 4PLs need more functionalities, e.g. to overview the supply chain in real time and in different levels of detail and to influence decisions according to occurring events which are either managed by the IoT system itself or by humans.

During the co-creation and exploration phases several logistics services were defined. However it was observed that participants selected a certain range of sensors even though the toolkit provided a much broader range. Furthermore, the application of sensors was very similar to existing processes and environments, i.e. the process and paradigm shifts required by the IoT concept were hardly discussed. One example is localization sensors (like GPS). These were only used for localization of goods or objects or for identifying positions (warehouse, transport tracking, etc.). Using the same sensors in more complex setup, in which an IoT system would decide independently about where the goods should be stored or where to gobased on other environment information, would have resulted in a different configuration with re-organised processes. This is

particularly relevant for new service development .Ideas from participants may even lead to new fields of application for existing sensors.

The challenge is to change the process based on capabilities offered by IoT technologies rather than improving the existing process. One reason for this is the behavioural change which is difficult to accomplish (Lewin, 1947). The new Windows 8 interface is an every-day example for the difficulty to change behaviour. Since users were conditioned to use the "start" button for decades, the absence of this button caused so many complaints, instead of motivation to change behaviour that Microsoft decided to integrate that button again.

Observations during the workshops indicate that experienced participants generate ideas comprising a larger number of sensors, and ideas for process re-engineering surfaced. Consequently, it is expected that LL participants will create more complex solutions over time by incorporating more diverse sensors.

Based on the feedback collected from living lab participants it was found that their knowledge about IoT increased. However the living lab couldn't fulfil their expectations regarding knowledge about IoT and its application potential; i.e. it is important to show in which areas IoT already provides relieves in daily life as well as in professional surroundings. Therefore, the development of an "IoT explanation toolkit" which does not have the whole functionalities but rather explains certain applications in different areas is discussed.

Combining the "IoT explanation toolkit" with exemplary cases and the full functional IoT toolkit for development within the experiential environment is expected to support the re-thinking of processes and the integration of more extensive IoT solutions. Introducing such supporting tool would be in line with the expectation that by providing enough explanation and support in order to understand the need to change, the change would be achieved more probably (Lewin, 1947).

These setup advancements would further be improved by adjustments of the graphical user interface and stability of the toolkit, in order to avoid boredom or dissatisfaction due to technical problems. Additionally, while on the one hand a toolkit for explanation is configured, on the other hand an 'advanced user mode' would support those who already gained more experience with IoT developments to adjust and improve their solutions.

## **DISCUSSION AND CONCLUSIONS**

In this paper we discuss the potential for a freight forwarder to improve the quality of data by using the IoT concept and thus having access to real time data. It shows how IoT services can be co-creatively developed and how this mightto support the use of innovative ICT in freight transport and logistics.

The proposed living lab approach with the tool kit improves the requirements elicitation for IoT services. However, interoperability problems may persist, since not all stakeholders are able support the solutions. The SoA approach,however, is based on applications per sensor and improves the ROI expectation and lowers the barrier to invest. Thus, developed solutions can be used in different scopes.

Next steps would be the preparation of an "IoT explanation toolkit" and the implementation of discussed improvements into the living lab. Further, developed services for temperature and humidity surveillance should be adjusted for application in food supply chain related services. Resulting services should be explored and tested within the living lab in order to investigate advantages and disadvantages, challenges and potential benefits of adoptive IoT solutions.

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# REAL-TIME COST PRICE-GRASP METHOD BY THE SUPPLY-DEMAND BALANCE MODEL

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## ABSTRACT

By the spread of recent cloud computer environment, we can collect the information of the environmental change in the real time. And it was enabled to grasp at the supply-demand balance in the real time. This helps the decision making of amount of production, and the decision making of the price for a change of the management environment. In addition, the supply-demand balance appears as a change of the cost. The purpose of this study is to build the algorithm to compute the product cost in real time from the information about the market environment change. Cost is computed with a structure matrix for each process combining Activity-Based-Costing and IDEF0 process modeling. It shows how the cost of each process will change due to the change of the actual sales volume and market price of raw material, etc. It enables to grasp the real time and detailed cost information.

## KEY WORDS:

Demand-and-supply balance, Activity-based-costing, IDEF0, structure matrix

## INTRODUCTION

In Japan, price competition intensifies at the recent low growth period. Therefore cost reduction and appropriate pricing becomes the key to management. The manager must think about a cost price under limitation of the sales price. The marginal income is the profit increment per 1 sales unit, and it is an index to use for short-term profit management. Decision making can reflect the cost change per product and one service unit quickly by paying its attention to differences between price and variable cost share.

In a service industry, there is how to catch marginal income by defining one service unit in various ways. Therefore a variety of marginal income management is necessary. There are difficult that only by the marginal income management that paid its attention to only in a single change factor, cost reduction and appropriate pricing. Therefore, the difference of a small expense is big and affects the profit if we do not decide a cost of equipment, personnel expenses, an original material cost carefully. Furthermore, I am big, and profit changes by the environmental change of the market, e.g., the estrangement of an expected volume and the real volume or the cost price change. Therefore it is necessary the model that can grasp what kind of influence the environmental change of the market has on cost and profit structurally.

Activity Based Management (following ABM) [1], [2] used Activity Based Costing (ABC) for cost management. The ABM is [(ABC + and other management information) + activity analysis + improvement reform practice]. In the ABM, an activity is defined by detailed ABC at first. And it is necessary for the number of times, cost to be shown definitely at the unit price, time. The activity model can provide numerical grounds to make decision of the improvement such as the reduction in a strategy of the product line individual treatment and a price, business amount of money grounds, useless work and waiting time. By the way of thinking of conventional accounting, we catch the cost change by the term beginning of the change of profit and the expense of the term end. By the way of thinking of accounting, it does not consider it what kind of cause cost changed for how during a period.

It is the cloud era, and, for customer needs to diversify, there is corporate management in response to an on-demand and robust to win in the present era maintaining the growth of the company. They grasp a financial condition in real time and perform the effect measurement within a short time in highly precise profit outlook, a dynamic cost-volume profit analysis, individual profit simulation, the real time of the individual management measure and need to do high managerial decisions is demanded there. The cloud computing technology can process the enormous real-time activity information of the company quickly. Therefore it is the times when we can utilize this technical environment. However, there is not yet the structure of the company organization which applies enormous data in management effectively in a short time of the minutes and second unit for a thing of cloud computing.

In the purpose of this study, we define the flow to calculate a cost change by the influence of the market environment change. Furthermore, we cope with market environment change, and detailed profit and loss to grasp cost and the earnings structure of a product and the service is to suggest a model.

## **COST CONTROL MODEL**

### **MODEL CASE**

The example of this study is a cafe of the counter form. The object of the business activity is processes from the visit of the visitor to clearing of the product. We assume store administration to perform this process repeatedly. The product to offer is one kind of coffee. As for the raw materials, coffee beans, the accessories are sugar, milk, spoons. The employee is one person in charge of the counter and one barista in charge of the cooking. The customer sits in the counter seat (ten seats) sequentially, and he is based on a flow to order coffee from. In addition, the investment necessary for facilities such as a central kitchen or the drinks machine includes it in materials unit price as a depreciation expense.

### **PROCEDURE OF THE COST CONTROL MODEL**

Firstly we make the model of business processes to intend for. Therefore we clarify a person, a thing and facilities necessary to carry out an activity. We use the Integrated Computer-Aided Manufacturing Definition Method (IDEF0) [4], [5] as technique to make a model.



### ACTIVITY COST MODEL

In order to visualize the structure of product cost, detailed cost is expressed by combining business process modeling and ABC (activity-based costing) through the Integrated Computer-Aided Manufacturing Definition Method (IDEF0) [1]. Structure Matrix [2] is used to express cost.

### IDEF0 BUSINESS PROCESS MODELING

Figure 1 describes the cardinal rules of the model of IDEF0. An activity is expressed in a box and any correspondence with the activity is shown through the four arrows. Activity (A) converts Input (I) into Output (O) by Mechanism (M) according to Control(C). In other words, Input (I) is converted by activity. Output (O) is provided as a result that input was converted by activity. Control (C) controls return by the activity. Mechanism (M) expresses resources (a place, person, and a machine) to carry out activity. These arrows expressing a thing are called ICOM.

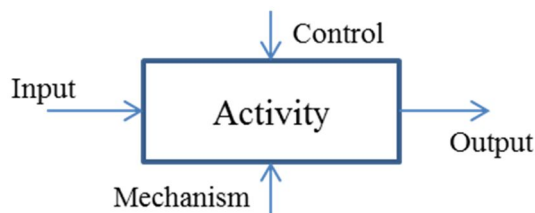


Figure 1 Cardinal rules of IDEF0

In this research, as a feature of business process modelling, an activity is expressed hierarchically as an embedded structure and the elements that flow from the start to the end of each activity are fixed. The fixed elements are a visitor, an order, and material. The flow of a visitor, who is the introduction of the total image, is shown in Figure 2. In this instance of a coffee shop, the process begins from the starting point, when a visitor comes to a store, opens a store at a point in time, and puts away the goods. This process is termed a visitor transaction.

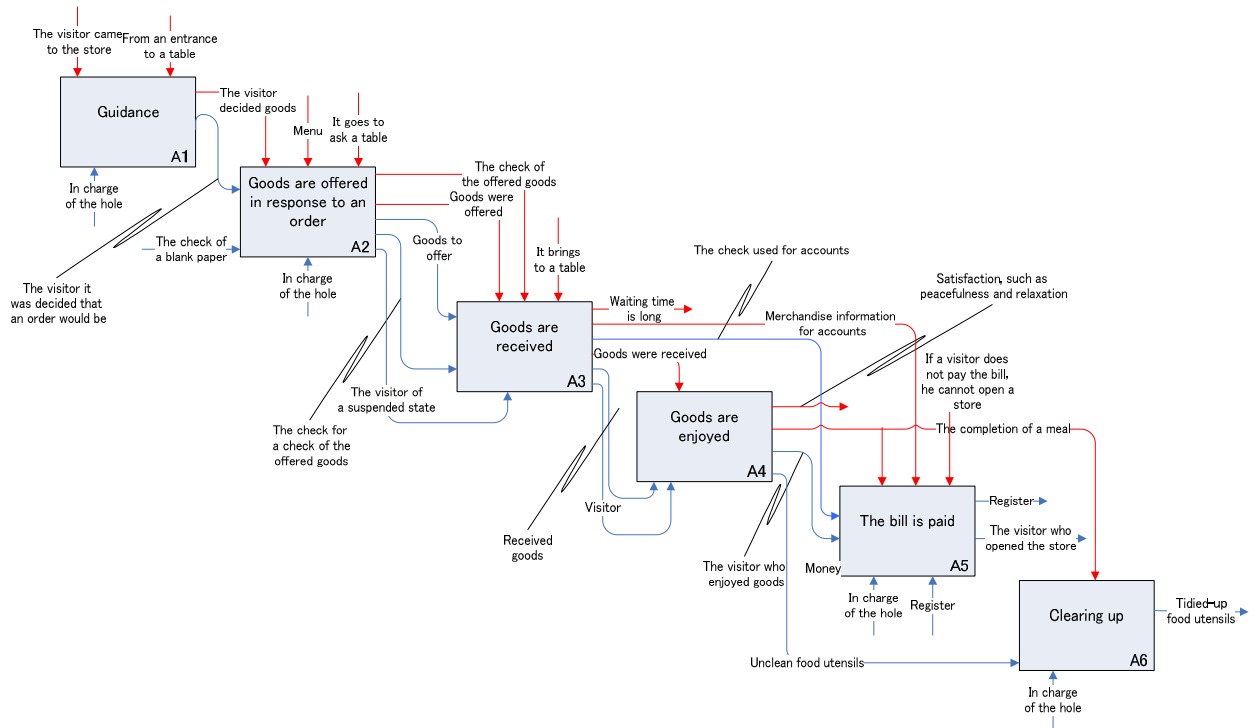


Figure 2 Process of a visitor transaction

It is assumed that operating activities are performed by repeating this process through various visitors. Thus, a visitor's flow and the person required for a visitor's purchase processing are described.

Next, the activity of "Goods are offered in response to an order" of the visitor transaction is divided into viewpoints (refer to Figure 3).

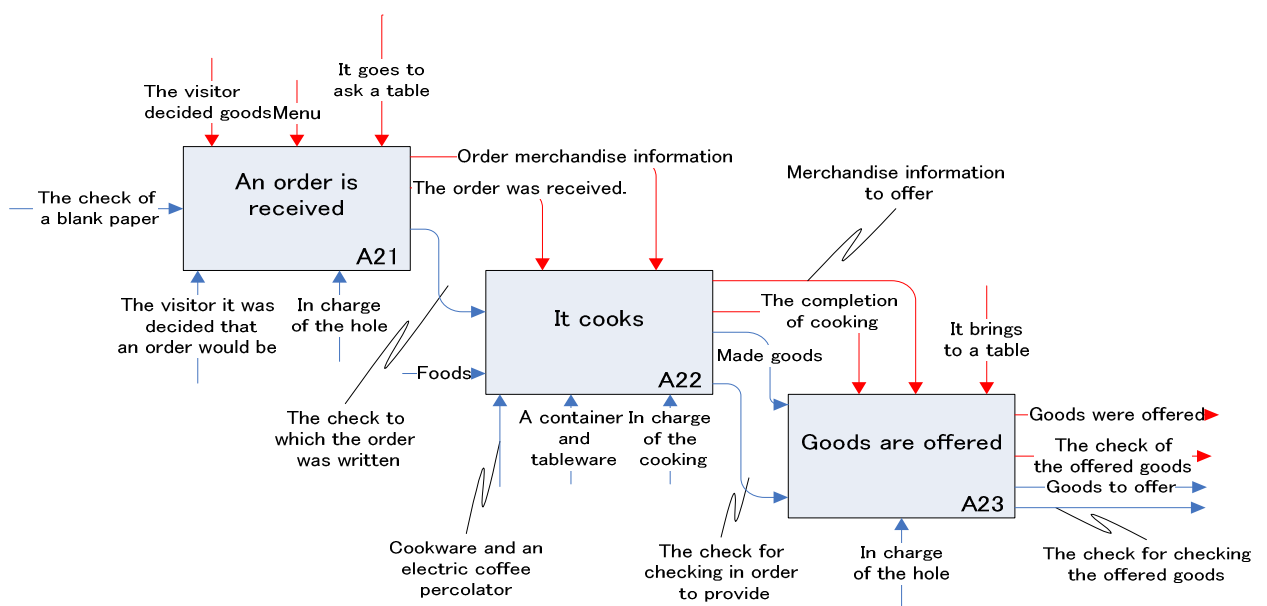


Figure 3 Process of an order transaction

Next, the flow of materials is divided into viewpoints through the activity of "cooking" of an order transaction (refer to Figure 4). This process fixes the flow of materials and the person required for the creation of the goods. Thus, the people and the activities required for each transaction are described with structure of the hierarchical structure of IDEF0 through a process in the shape of a nest, which can be easily understood in detail.

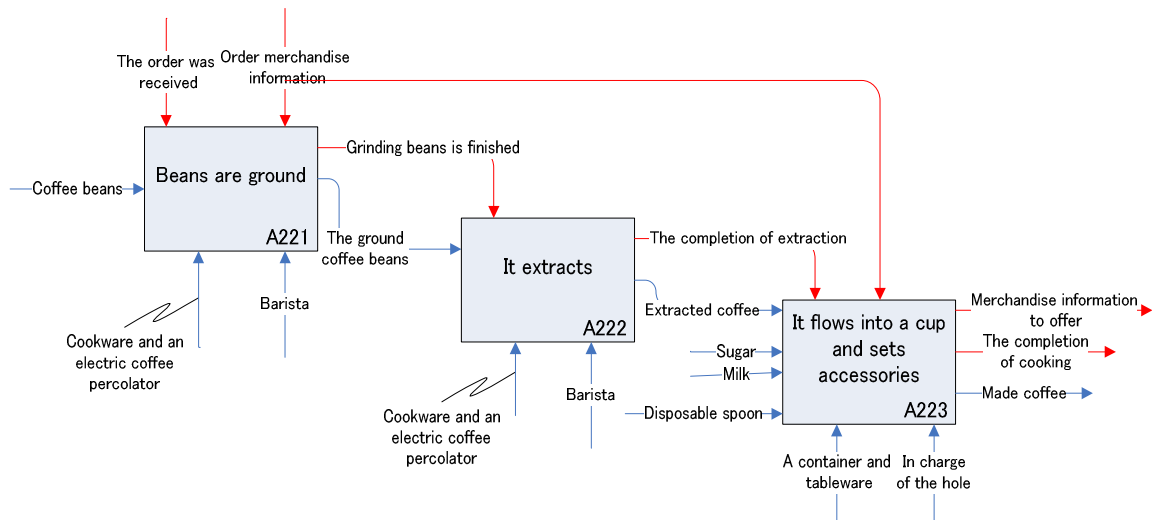


Figure 4 Process of a material transaction

### COST STRUCTURE MATRIX

The cost of ICOM is expressed through a Structure Matrix for each transaction that is carried out. For example, through the foundations of a Structure Matrix (as shown in Figure 5), the number of cars to be manufactured and the amount of materials required to do so are first put into the upper part of the matrix. Next, the numerical values in the central part are multiplied and the resulting numerical values are added in a transverse direction. The necessary quantity of steel, which is the material required to manufacture a car, is computed on the left side. Next, this quantity of steel is moved to the upper part, where it is similarly calculated.

Thus, the disassembly of parts and the structure of an assembly can be described.

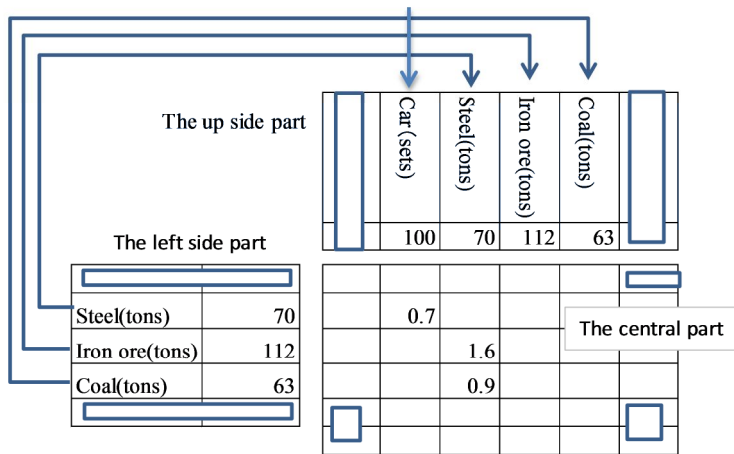


Figure 5 Basic operation of Structure Matrix

**CALCULATION OF THE COST MATRIX USING THE STRUCTURE MATRIX**

In figure 6, we express cost using a structure matrix for each transaction as example of the coffee shop. Figure 6 expressed materials transaction. The numerical values and multiplication of the central part corresponding to a lengthwise direction for the numerical value of the upper part are performed. The result is added to the numerical value corresponding to the transverse direction of the central part, and the numerical value of a left part is computed. This basic operation is called "perpendicular multiplication and horizontal sum."

Calculation of a structure matrix begins from the upper left of the central part. First, the process involved in a material transaction is determined, and a product is disassembled. In the coffee shop example, the coffee that is served is the output, which is described by "the flow of coffee into a cup and the setting up of accessories" of the material transaction. This is located first.

It is then divided into the inputs for the activity; the necessary quantity is then computed. This is performed for all the activities and it continues until the third row of the six lines of the central part.

After this, a process is followed in a particular order, whereby the personnel expenses and the fixed cost and each activity cost is calculated.

Each expense is then divided into variable costs and expenses, and a fixed cost (if the calculation is finished to the last activity), and the total is calculated.

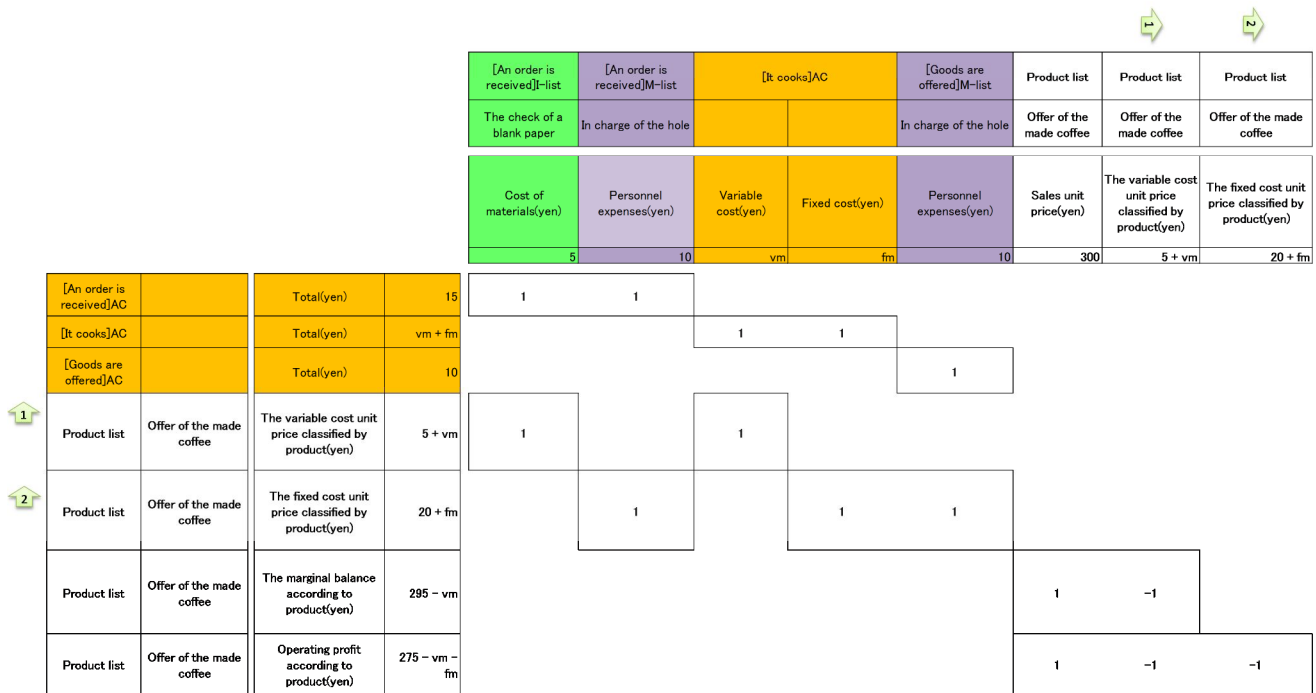


Figure 6 Cost Structure Matrix of an order transaction

A marginal balance is computed by subtracting the variable costs and expenses from a sales unit price. In addition, a fixed cost is subtracted from a marginal balance and the operating profit is computed. Further, let each numerical value be regarded as a parameter. A cost Structure Matrix is similarly created about an order transaction and a visitor transaction. Given that the output cannot be divided into an order transaction and a visitor transaction, the cost is described in terms of ICOM of each activity and only the activity cost is calculated.

**PARAMETER INFLUENCE ANALYTICAL MODEL**

The information of the condition change to handle in this study is five points of Change of a real volume change, a market stocking price change, the change of the loss rate and a change of the processing time, the number of the facilities, the number of employees. It is defined these five information in flow chart how change as a parameter (material cost, a cost of equipment, personnel expenses).

And the flow chart is illustrated.

Next, we make a parameter calculation list based on flow chart.

When it thinks about a cost of equipment, it is coffee maker, container and cash register to be classified in the cost of equipment. As for this cost of

equipment, cost per one cup changes by a real sale volume. If there are fewer real sale volumes than the volume of the prediction, the costs of equipment per one cup increase. Therefore, as information of the market environment change, a real sale volume is spent, and a real cost of equipment is calculated.

It increases facilities and workers if we do not meet a current limitation condition when a parameter of the number of the sale was decided and in this way lets the cost calculation by the cost structure matrix reflect it. We set the volumes of the expected sale on this condition. Therefore, we understand how the number of the facilities and number of the workers change at that time. Furthermore, I become able to grasp the influence on activity cost by it, too. In other words, appropriate management of the associate fixed costs to secure profit is able to manage.

#### **PARAMETER CALCULATION ALGORITHM**

If the information on the changing market environment (such as volume of sales) is actually supplied as a parameter in the cost Structure Matrix of an activity cost model, how does a parameter change? The algorithm that computes the parameter is built, and this study defines it as a parameter calculation algorithm. Additionally, the information on changing market conditions is treated by cloud computing technology as "volume-of-sales change" and "market prices." In a store, when a fixed cost is considered concretely, it is classified into cookware, a container, and a register. This fixed cost changes the cost of each cup with the actual volume of sales. If the actual volume of sales is less than the predicted volume, the fixed cost per cup will increase. Then, the volume of sales would actually be supplied as information on a changing market environment. Thus, an algorithm, where an actual fixed cost is calculated, can be built (refer to Figure 7).

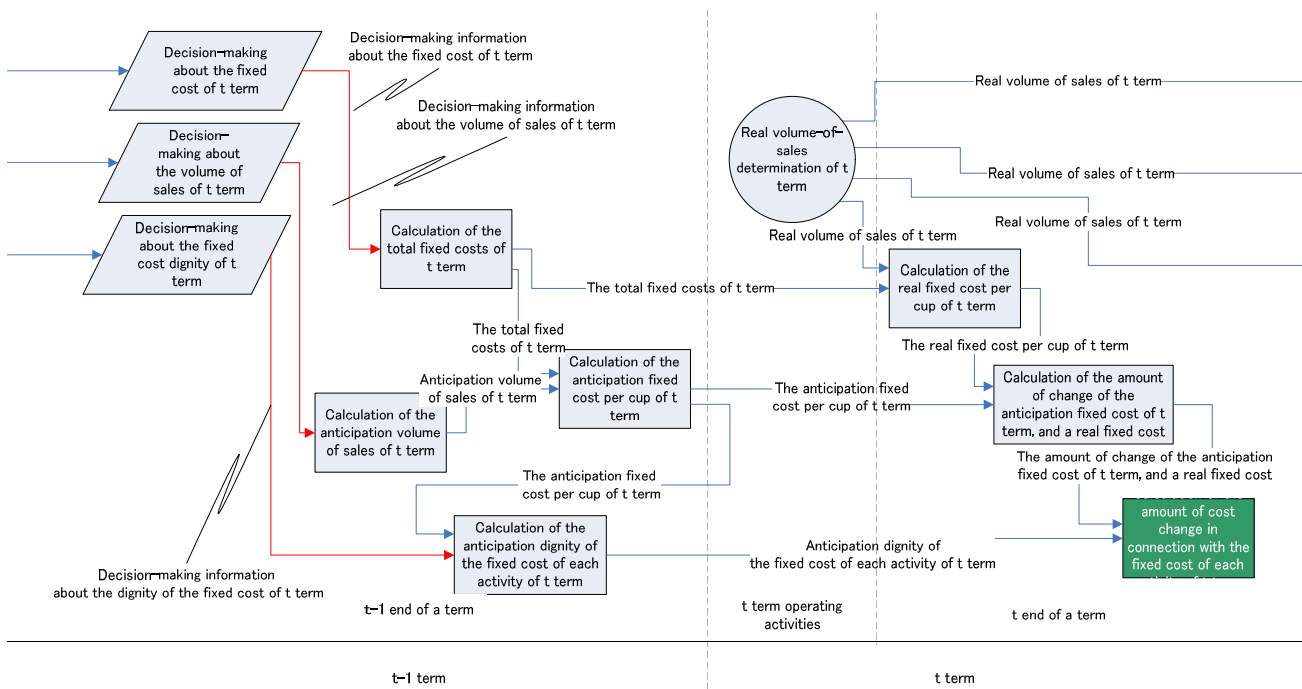


Figure 7 Algorithm of fixed cost calculation

With regard to the cost of materials, the volume of sales is actually determined by the operating activities of the  $t-1$  term, and decision making in terms of the kind of material to be used in the  $t-1$  end of a term using the information is performed. If the used material is determined, although a stock is laid in, the market price will affect the input price in that case. Completion of stock will determine the cost of materials of the  $t$  term. Since the cost of materials is variable, the cost of materials does not change with the results of the operating activities of  $t$  term. This is then repeated. Therefore, the information on the changing market environment, which the cloud supplies in terms of the cost of materials, includes the "actual volume of sales" and "market price" (refer to Figure 8).

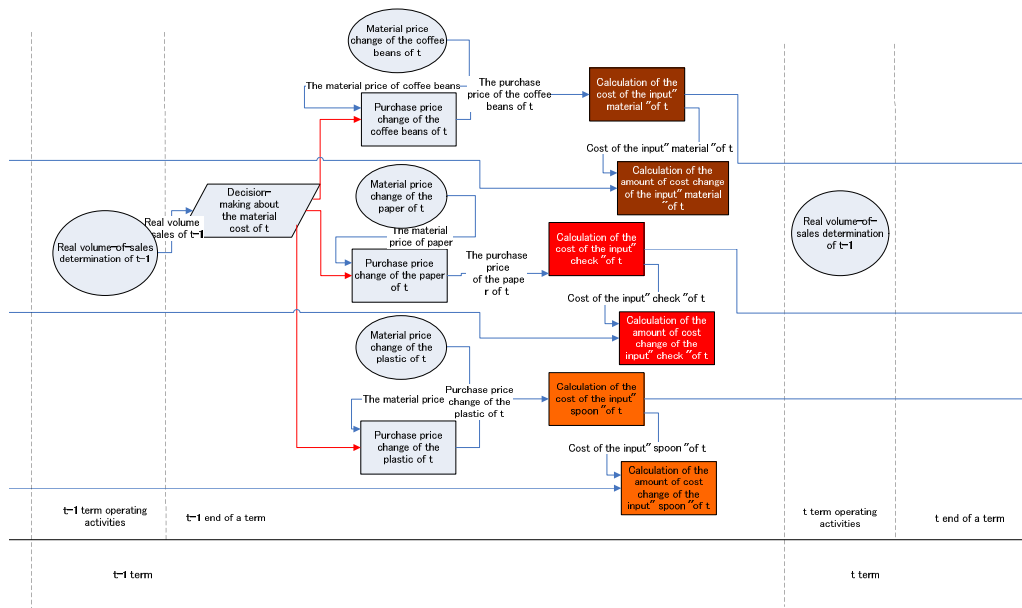


Figure 8 Algorithm of cost-of-materials calculation

## CONCLUSION

The market information is collected through cloud computing technology and supplied to a parameter calculation algorithm. And each parameter of the fixed costs, the labor costs and the material cost are calculated, and it is spent by an activity cost model. After having expressed ICOM of each transaction by IDEF0 process modeling and activity cost in a cost structure matrix, a calculated parameter is spent. When a parameter is spent, a calculation is carried out in a cost structure matrix, and activity cost and a profit and loss calculation of each transaction are carried out. When the information of the market environment change was given, we can grasp influence on profit and loss and can understand the details of the structure of the cost. This information is given back to a user as cost information depending on the period when a user set it. Given that cost is calculated whenever the market information is supplied through cloud computing, cost fluctuations can be caught in real time. When a financial condition changes, the change to profit can be easily grasped in real time.

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# COMPARATIVE ANALYSIS OF CLOUD ERP

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## ABSTRACT

The emerging technologies of Cloud Computing, Software-as-a-Service (SaaS), Multi-Tenancy, and Mobile Computing have the potential to significantly alter the future Enterprise Resource Planning (ERP) space and become the core architecture for ERP systems. A survey gathered insights from 37 participants representing different companies to gain a deeper understanding of the current status of ERP systems and the future emerging technologies applied to these systems. The survey results from these professionals and related statistical analysis show that the emerging Cloud ERP systems outperform the traditional legacy ERP systems in all important characteristics of *Accessibility, Business Cost, Implementation Time, Mobility, Scalability, Upgradeability, and Usability*. Cloud ERP Systems were also found to have a shorter implementation time and a larger proportion of cloud systems operated on the most recent version of the software. Furthermore, the survey analysis revealed that the industry professionals identified Cloud Computing, SaaS and Mobile Computing as the emerging technologies of the coming decade, regardless of the type or size of different companies. This paper provides a background for the above technologies and details the survey results as to why the use of emerging technologies and a shift to Cloud Computing systems will be the technology transfer for the future.

## INTRODUCTION

More than two decades ago, Enterprise Resource Planning (ERP) systems gained a foothold in modern organizations. With this shift in business computing, these systems became an enterprise's central repository for data and allowed for integrated business processes. Creation of these interconnected enterprise systems led to significant benefits for organizations which enabled them to manage and automate tasks globally.

However, problems which began to surface included the capacity to manage a software application on a global scale, the ability to update the system with technological changes, and the capability to modernize the system with changing business demands. Many Legacy ERP Systems were developed before our current internet age and computer infrastructure. To keep up with changes in the business environment these systems have been cobbled together in an inefficient and outdated manner. It is not surprising that Gartner, a leading information technology research firm, has reaffirmed this outlook estimating that 55% to 75% of all ERP projects fail to meet their objectives.

Technology has dramatically changed since ERP Systems first became a core aspect for organizations. Due to advances in computer technology both in software and hardware, the fundamentals of how to design an ERP System have changed. Modern approaches allow for a ground up rethinking of the infrastructure used to develop these systems. Cloud ERP Systems built on a Multi-Tenanted framework and delivered by Software-as-a-Service (SaaS) could significantly alter the current ERP space.

Organizations aspire for their systems to be globally accessible, easily managed, user intuitive, cost friendly, and straightforward to upgrade. This research explores the possibility that the architecture of cloud computing could bring forth many of these benefits. An industry survey was conducted to provide quantifiable findings about the application of cloud computing in the field of ERP.

## ENTERPRISE RESOURCE PLANNING

Developed as a natural extension of Material Requirements Planning (MRP) systems, ERP systems emerged in the late 1980's with a wider set of application functionality. These systems aimed to integrate core functions of an enterprise including:

- **Financials:** Utilized to serve the needs of employees in the finance department. This model typically includes the General Ledger, Asset Management, Project Accounting, Accounts Receivables, and other related financial reports.
- **Manufacturing:** Manages all associated pieces of the production of goods. This module generally encompasses Bill of Materials, Work Orders, Scheduling, Capacity, Quality Control, and other manufacturing planning/control activities.
- **Human Resources:** Focused on the management of employees and associated benefits. This module usually consists of Recruiting, Training, Payroll, Benefits, Retirement, Talent and Time Tracking.
- **Project Management:** Dedicated to tasks related to accomplishing a specific goal. This module contains Project Planning, Resource Planning, Project Costing, Work Breakdown Structure, Billing, Time and Expense, and Activity Management.
- **Supply Chain Management:** Responsible for managing the network of interconnected businesses involved in a company's line of work. This module includes Supply Chain Planning, Supplier Scheduling, Order to Cash, Purchasing, and Inventory Management.
- **Customer Relationship Management (CRM):** Built to manage a company's communications with customers, sales partners and new business prospects. This model is made up of Sales, Marketing, Customer Service, and Technical Support.

ERP systems have proved their importance to enterprises and organizations of all types including government, education, and non-profit. The ability to seamlessly connect information across an organization provides value in planning, decision making, reporting, and centralization of data management. Because core functional areas do not operate independently, having a centralized set of data/information allows organizations to have a consolidated view of their entire business. Although ERP systems have many benefits, problems continue to persist with organizations facing cost overruns, longer implementation, and unachieved objectives.

## CLOUD COMPUTING

Although the concept of Cloud Computing was theorized as early as the 1950's, it wasn't feasible for implementation until the mid-90's due to improved servers, modernized data centers, and a faster Internet connectivity. Cloud Computing is the delivery of computing as a service where shared resources, software, and information are provided to computers as a utility over the Internet. Cloud Computing can be separated into three main areas:

- **Infrastructure-as-a-Service (IaaS):** Model in which equipment used to support operations is outsourced. Generally referred to contracting out servers, storage, hardware, and networking components.
- **Platform-as-a-Service (PaaS):** Service where a customer creates software using tools from the provider and the provider handles all back-end support for the applications including the network, servers, and storage.
- **Software-as-a-Service (SaaS):** Software delivery model in which software and its data are hosted online and the user can access the information through the Internet.

Cloud Computing is a significant advancement because it allows many advantages for both the system's end users and the service providers. The end user is no longer tied to a company's internal network or data center; the information is accessible anywhere through the internet. The provider also has a number of advantages including: greatly simplified software installation, easier maintenance, and central control over versioning.

## **CLOUD ERP SYSTEMS**

An ERP system that utilizes a cloud computing platform architecture is considered a Cloud ERP system. These systems operate with a SaaS model and typically utilize a Multi-Tenanted framework. Multi-Tenancy is a form of software architecture where a single version of code runs on a server serving multiple client tenants. In Multi-Tenancy software architecture an organization's data is served as a single occurrence by a hosted application that many customers can use. A tenant is defined as an instance of an organization's data. This allows multiple tenants of different organization's data to be based on the same shared hardware and software infrastructure.

Relatively a new concept, Cloud ERP first emerged with NetSuite, founded in 1998, and Salesforce, founded in 1999. Both of these systems originally focused on small and mid-cap organizations concentrating on a niche within the full breath of ERP functionality. For much of the early 2000's Cloud ERP remained "emerging" with only a handful of companies operating in the space. Although, as technology advanced with greater internet bandwidth, faster operating speeds and cheaper storage costs, a cloud based model became more attractive. Workday, founded in 2005 by the original founder of the ERP giant PeopleSoft, differentiated their application by targeting medium and large-cap organizations. Subsequently all major industry players have now begun to investigate a cloud model for their systems due to Cloud ERP's recent successes.

Industry experts have promised that Cloud ERP will provide the opportunity for businesses to completely transform how they use and pay for Information Technology (IT). One of the selling features is the implication that an organization can reduce their IT support costs by outsourcing hardware and software maintenance, and support to the SaaS provider. Another potential advantage for a cloud system is that version control is performed by the provider allowing for application upgrades to occur for all system users at the same period of time. This implies that an organization will no longer have to perform reimplementation upgrades every three to five years to stay current with technological and business advancements; a problem that currently plagues the industry. An additional benefit that has been circulated is that Cloud ERP can utilize the full advantages of the internet and will include new features that were not possible using older technology.

## **KEY SURVEY FINDINGS**

In order to gain perspectives from ERP system user's, a survey was conducted which gathered responses from 38 professionals representing different companies. Each respondent was asked a series of questions relating to:

- Characteristics that they feel are important for an ERP System
- The performance of their company's prior and current ERP Systems
- Their opinion on ERP emerging technologies

The professionals in this survey had a range in backgrounds having worked with various ERP Systems, for different industries and for diverse sized companies. Their profile consisted of twenty manufacturing companies, nine service companies and nine companies classified as "other." The majority of companies in the survey were considered large, but responses did included feedback from six small companies and seven medium companies.

### **Important Characteristics**

The first section of the survey focused on what characteristics users felt are important in their company's ERP Systems. Participants were asked to rate seven characteristics associated with ERP Systems: *Accessibility*, *Business Cost*, *Implementation Time*, *Mobility*, *Scalability*, *Upgradability*, and *Usability*. Each characteristic was rated on a five point scale with one being "unimportant" and five being "critical." For every characteristic a definition was provided to establish conformity in the user responses.

The definitions that were provided in the survey are as follows:

- **Accessibility:** The degree to which a system is available to as many people as possible such as self-service.
- **Business Cost:** The cost associated with running the system; both upfront and continual costs.
- **Implementation Time:** The time it takes to execute either a complete or a new version of an ERP System.
- **Mobility:** The ability to access the system from as many places as possible including mobile devices.
- **Scalability:** The ability of a system to handle a growing amount of work in a capable manner.
- **Upgradability:** The ease in improving the functionality of the system.
- **Usability:** The ease of use and learnability of the system's interface.

Results in Figure 1 show the average level of importance ERP users felt about each of the seven characteristics. As an average of the total responses participants felt that *Usability* was the most important characteristics and *Mobility* was the least important characteristic. Notable from these results is that every characteristic defined in this survey was considered important for their company's ERP system. This data is a base line when comparing how well each system type, Cloud or Legacy, measured up with these same characteristics.

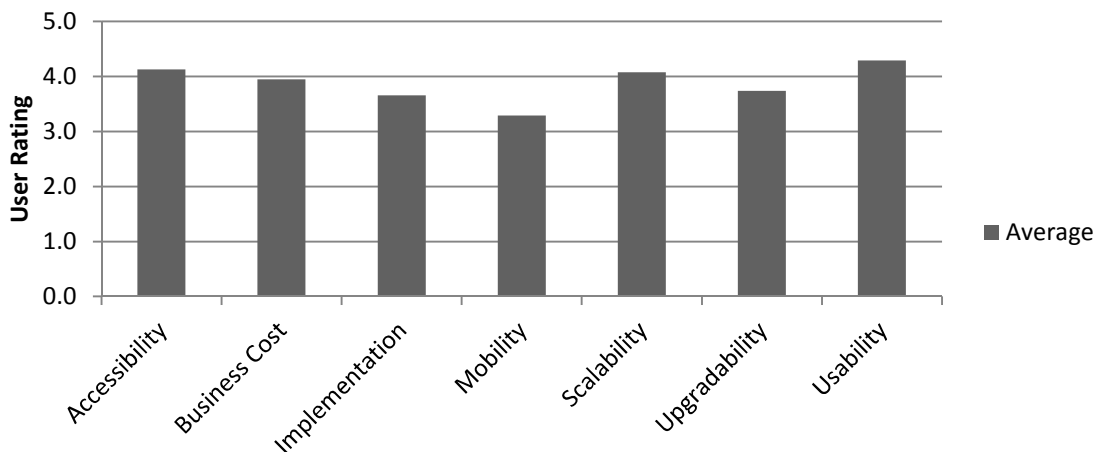


Figure 1: Average Importance of Characteristics

An ANOVA model with a follow-up Tukey Test has shown that the characteristic *mobility* was statistically the least important characteristic to ERP users. A p-value of 0.000 indicates that there is a low risk of making Type I error. All six other characteristics were found to have variability in their average ratings but were not statistically different from one another. However, all seven characteristics in the survey received a rating of "Important" or greater.

### Cloud vs. Legacy Systems

The second section summarizes data on how participants responded about the different systems their company either currently uses or has used in the past. Every ERP user was asked to provide ratings on ERP Systems they have worked with. The ratings were conducted by characteristic, on a five point scale, with one being "poor" and five being "excellent." A total of 77 systems were rated by the 38 participants who took the survey. Once all scoring had been received each ERP System was determined to be either Cloud or Legacy, and then summarized accordingly.

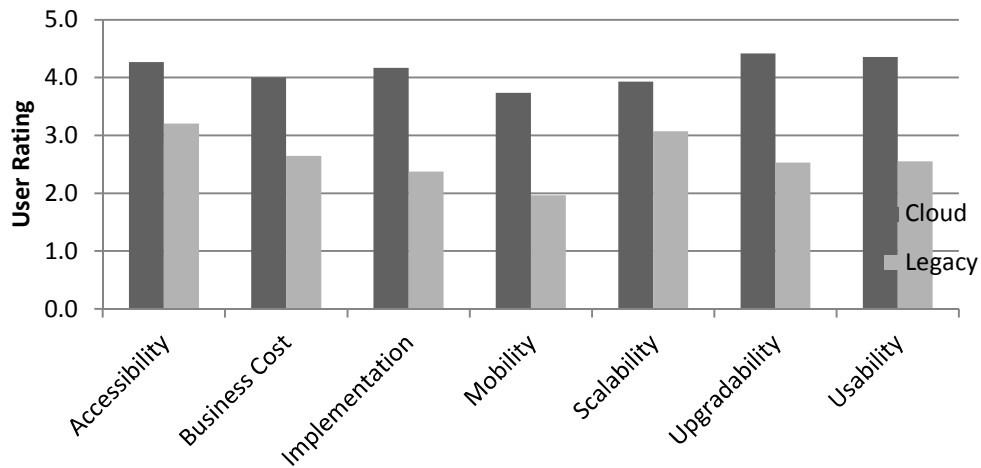


Figure 2: Average Rating of ERP Systems

The survey results, as displayed in Figure 2, illustrate the average user rating when comparing each characteristic for the systems rated by whether the system was a Cloud ERP System or a Legacy ERP System. Seven separate T-Tests showed that there were statistically significant differences between the rating of Cloud Systems and Legacy Systems. The values from the T-Tests are as follows: *Accessibility* (p-value 0.000), *Business Cost* (p-value 0.000), *Implementation Time* (p-value 0.000), *Mobility* (p-value 0.000), *Scalability* (p-value 0.005), *Upgradability* (p-value 0.000), and *Usability* (p-value 0.000). In all seven statistical tests users had a higher level of satisfaction with Cloud ERP Systems compared to Legacy ERP Systems. This finding provides strong evidence that Cloud Systems are outperforming their Legacy System counterparts.

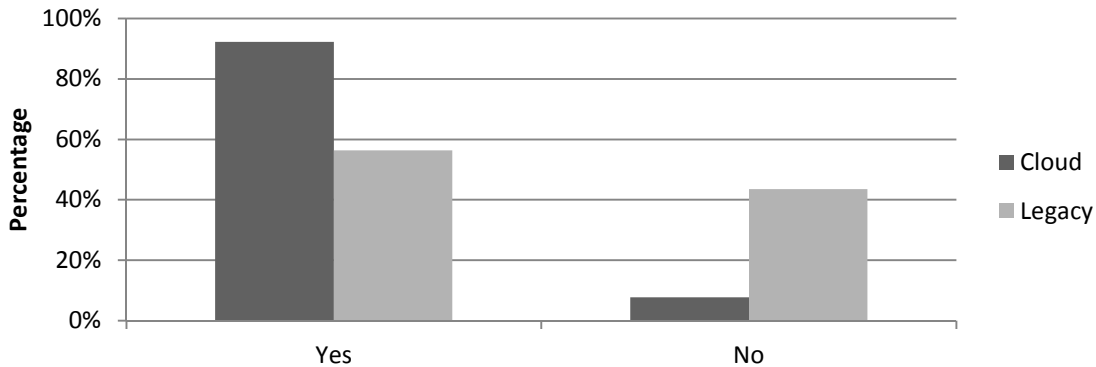


Figure 3: ERP Systems on Recent Version of Software

Data from the survey, as reflected in Figure 3, shows the responses to when users were asked if their current ERP system was on the most recent version of software. This information was summarized for all Cloud Systems contrasted to all Legacy System. The responses were then compared with a test of differences between two population proportions. A p-value of 0.000 indicates there is strong evidence that the two proportions are statistically different. The test found that a statistically larger proportion of Cloud ERP Systems are on the most recent version of software. Being on the most recent version of software is a key benefit for enterprise systems since performing a reimplementation is very costly. The ability to easily update to the most recent version of software will allow applications to stay current with changing technological and business demands; a potential to becoming a marketplace differentiator.

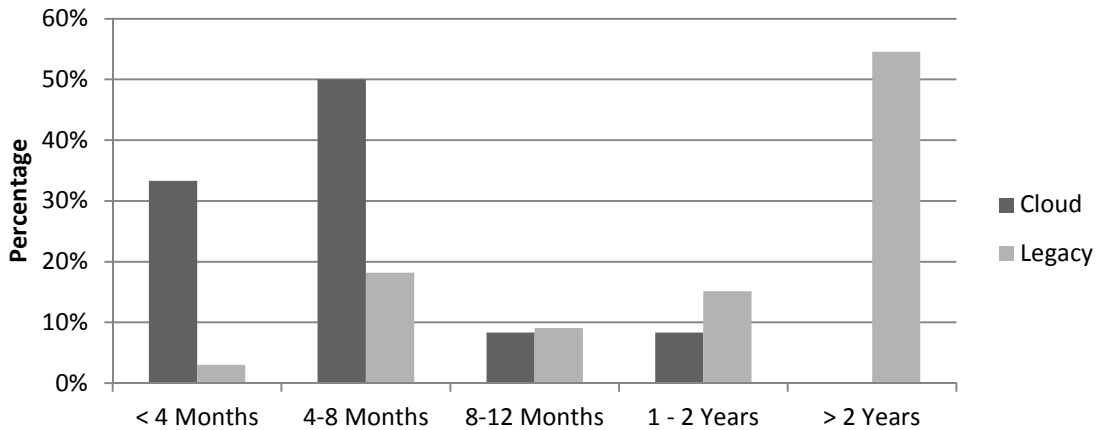


Figure 4: Implementation Time of ERP Systems

The survey data in Figure 4 refers to the question which asked participants how long the implementation of their system took. This data was then summarized based on if the system was a Cloud System or a Legacy System. A T-Test with a p-value of 0.000 has shown that the implementation time for a Cloud System and a Legacy System are statistically different. Cloud Systems were found to have a significantly shorter implementation time than Legacy Systems. On average Legacy Systems took 27.67 months longer to implement than Cloud Systems.

The Cloud ERP data differences could also be from unrelated reasons including reduced system implementations, smaller company sizes and less involved change management considerations. However, Cloud ERP implementations operate by gathering requirements and configuring the system to the organization's needs, while Legacy ERP implementations offer a high degree of customization. By allowing a great amount of configuration but limiting customization an implementation is able to save an enormous amount of time and cost on development efforts.

### Emerging Technologies

The final section of the survey encapsulates the responses from ERP users when asked open-ended questions about emerging technologies and future trends. The answers from the survey participants are important to understand their mindset towards emerging technology and the direction they feel ERP Systems are evolving.

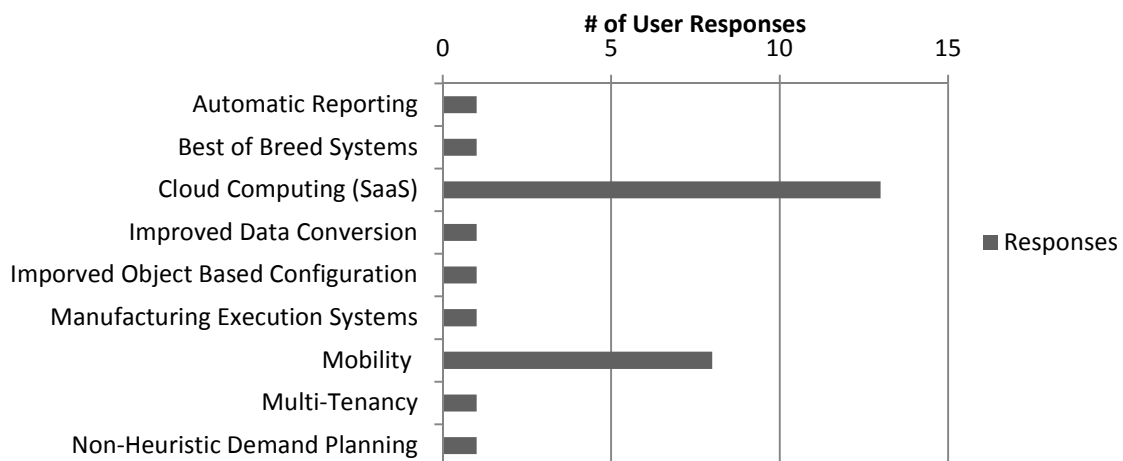


Figure 5: Top Emerging Technologies for ERP Systems

The results as shown in Figure 5 detail the responses from the open-ended question participants were asked, "In your experience/opinion, what do you think will be the

dominating emerging technology for ERP Systems in this decade?" The summary of those results is shown in the figure with most users determining that Cloud Computing, SaaS, and Mobility were the most important technologies in this upcoming decade. These results are intriguing since the same respondents that ranked Mobility as a top Emerging Technology for ERP Systems also ranked Mobility as the least important current characteristic, as shown in the section "Important Characteristics." One possibility that could be hypothesized is that although right now mobility is the smallest issue in their work, when compared to the other characteristics, the participants feel that mobility will become very important in the future.

To determine if a participants company's size or type of business affected their outlook on the top emerging technologies of the next decade, multiple tests for the differences between different populations were performed. Three separate tests were performed to conclude if the users company's size altered their viewpoint; small vs. medium companies, medium vs. large companies, and small vs. large companies. Another three tests were conducted to establish if the participants company's type of business changed their outlook; manufacturing vs. service, manufacturing vs. other, and service vs. other. The results of all six tests yielded high p-values which indicate that the null hypothesis cannot be rejected and each test of differences between any two population proportions are not statistically different. This confirms that choice of Cloud Computing, SaaS, and Mobility as the emerging technologies of the next decade is not based on the participants' company's size or industry type.

A separate question conducted in the survey asked participants, "Have you considered using a Cloud Computing ERP System?" The respondents' feedback indicated that 61% of them have thought of a Cloud ERP System for their company. One ERP user who answered "Yes" replied that "Cloud-based hosting and delivery will win, as there's too much time and money in the current customer deployment model for it to not be attacked and innovated against."

## **CONCLUSION**

The survey results and related analysis show that Cloud ERP Systems outrank Legacy ERP Systems in all important characteristics - *Accessibility, Business Cost, Implementation Time, Mobility, Scalability, Upgradability, and Usability*. A substantial number of users were more satisfied with systems classified as a Cloud ERP System when compared to traditional Legacy Systems. Cloud ERP Systems were also found to have a shorter implementation time and a larger proportion of these systems were on the most recent version of software. These findings additionally reveal that Cloud ERP Systems are able to be set up faster and require significantly less maintenance to keep the systems current with technological and business advancements. Furthermore, industry professionals identified Cloud Computing, SaaS, and Mobility as the emerging technologies for ERP over the coming decade.

The findings demonstrate that there are significant benefits for companies to use ERP Systems built using cloud architecture. This research provides new quantifiable discoveries that impact enterprises and the ERP vendor marketplace. The results provide evidence that cloud computing poses to become a disruptive technology in the field of ERP systems. Large mainstream ERP vendors have already begun to realize that cloud architecture is a key differentiator and that a dramatic shift in business computing is now underway.

*Due to page limitation requirements, additional analysis and related discussion were not included in this article. The interested reader may refer to the second reference below, "Comparative Analysis of ERP Emerging Technologies," for more detailed information.*



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# COMPARING THE BENEFITS OF RFID AND BARCODE-BASED TRACK AND TRACE IN THE RECONFIGURATION OF DISRUPTED SUPPLY CHAINS: AN EMPIRICAL STUDY

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## ABSTRACT

Radio frequency identification (RFID) technology continues to gain popularity in businesses as a means to improve operational efficiency and bring about cost savings. However, there is a gap in the literature exploring the enhanced use of RFID to substantially add value to supply chain operations. One of these enhanced uses is leveraging the enhanced track-and-trace capabilities offered by RFID in order to facilitate efficient reconfiguration of a supply chain logistics network in the event of a disruption. This paper presents a simulated model of a supply chain logistics network using a multi-agent. It is comprised of autonomous and intelligent agents representing the key entities in the supply chain. We use this multi-agent system to run a series of simulations examining the benefits of RFID over a traditional barcode-based tracking system in helping to efficiently reconfigure supply chains under varying levels of collaboration between partners in response to dynamic disruptions in production at key members of the supply chain. Our results suggest that RFID is able to reliably produce greater savings in our model, both in terms of cost and distance travelled, than a barcode-based system.

## INTRODUCTION

Radio frequency identification (RFID) technology is an increasingly popular technology for tracking and tracing goods in the supply chain activities in relation to logistics, warehousing and manufacturing. RFID uses radio wave transmissions between data carrying devices (known as RFID tags/transponders) and data receiving devices (RFID readers/interrogators) [1]. The information stored on the tags is transmitted to the readers and then passed onto middleware for use in various applications. This information is unique to the item to which the tag is attached to, such as date of production, batch number, shipping detail, and expiry dates, depending on the intended application. For instance, when each carton within a shipment is tagged, the haulier is able to easily and accurately monitor its real-time location, status, destination, value, contents and so on throughout its delivery route to the customer. The benefits of RFID have made it an increasingly popular for identifying goods in the supply chain, partly due to the fact that its operational characteristics outperform barcodes in many ways [2].

In comparison to barcodes, RFID does not require direct line of sight, and multiple tags can be read simultaneously. Furthermore, tags are able to accumulate information over a period of time (e.g. as the tagged item passes through the supply chain) and to have their existing information altered. Other benefits particularly useful for supply chain applications include unique identification of each tagged item and status monitoring,

improved stock visibility and traceability, automated inventory counts, automated manufacturing operations, increased product availability and reduced shrinkages [1],[2].

In real world supply chains, all parties face challenges in terms of improving operational efficiency and reducing operating costs as much as possible. One key potential source of efficiency loss and additional cost is when a disruption occurs within the supply chain. A disruption may take the form of a vehicle breakdown or the failure of production equipment, and may cause delays in production and additional costs due to missed delivery deadlines. When such a disruption occurs, it is extremely important to be able to reconfigure the supply chain quickly and efficiently.

In this paper, we propose a multi-agent-based model of a supply chain network which serves to illustrate how the use of RFID technology can help to efficiently reconfigure and optimise a supply chain network and related logistics operations in response to dynamic changes due to disruption. Specifically, we model in our multi-agent system a three-tier supply chain composed of supplier, manufacturer and retailer agents, and run a series of experiments to investigate the effectiveness of RFID and barcode-based technologies in reconfiguring the supply chain and logistics operations when a disruption occurs due to the failure of production facilities at a manufacturer. We test the efficacy of RFID technology versus barcodes using two different reconfiguration techniques, which serve to model supply chains with both low and high levels of communication.

This paper is organised as follows: Section II discusses current research in RFID and the use of multi-agent systems in the literature. Section III discusses the architecture of the multi-agent system developed in this research and explains how RFID technology and barcodes are represented within the model. Section IV explains how we introduce disruption into the model, and describes how the two reconfiguration techniques we use in our model work to correct this disruption. Finally, Section V gives a conclusion to this paper and outlines avenues for future research.

## **LITERATURE REVIEW**

### **Radio Frequency Identification**

In the last decade, there has been a significant growth of academic articles published in the RFID literature. There are two main groups of research contributing to the adoption of RFID technology, namely technical aspects and applications. The focus of this paper is on the applications aspect of RFID, and so the focus of this subsection will be on the RFID applications literature. Manufacturing is one of the major application areas in the RFID literature. With RFID collecting real-time information, Yin et al. [3] developed a precast production management system to inspect incoming materials, production inspection, and logistic and receiving management. In logistics, Hellstrom and Johansson [4] examined the impact of different control strategies on the returnable transport items with a simulation model, Ola and Henrik [5] and Lin [6] conducted surveys to assess the use of RFID and its impact on logistics performance, and Lee and Chan [7] developed an efficient reverse logistics system with RFID incorporated. Despite the broad and expanding RFID applications literature, one significant aspect of research which is not currently being investigated is the exploration of extensive use of real-time RFID data to improve and add substantial value to business operations by, for example, aiding in the reconfiguration of supply chains and distribution networks in response to unexpected disruptions. This area of research is vital in demonstrating the potential of RFID as an investment opportunity by illustrating its ability to provide reductions in costs and improvements in efficiency. It is because of this importance that this application area forms the focus of this research. We use a multi-agent system to model a three tier supply chain and logistics network. In the following subsection, we provide some examples of related work from the multi-agent systems literature.

## **Multi-agent Systems**

Multi-agent systems enable us to model a number of properties which are commonly present in supply chains, including uncertainty, decentralised decision making by self-interested agents and the process of self-organisation by participants. A software agent is a computer program that acts on behalf of a user, and a multi-agent system is a collection of multiple intelligent software agents which interact within an environment. Interactions between agents are usually conducted under the constraints of limited information about the environment and system as a whole. Multi-agent systems allow large global problems to be decomposed into multiple smaller problems which are solved by the agents [8]. The characteristics of MAS can be well applied in the systems that have the need of achieving optimality and increased responsiveness, agility, adaptability, extensibility, and reliability. Because of the suitability of multi-agent systems for modelling supply chains, the multi-agent supply chain literature is broad, with a number of different subfields having emerged. Of particular relevance to this paper is agent-based supply chain management. Supply chain management is the process of planning, managing, monitoring and controlling a supply chain with the aim that products flow through the business network in the minimum time and at the minimum cost possible [9]. This process is often coordinated through negotiation. The basis for many agent-based models of negotiation lies in the seminal Contract Net protocol [10]. The authors detail a protocol for distributed problem solving, defined as "the cooperative solution of problems by a decentralized and loosely coupled collection of problem solvers", which is referred to as the contract net. The Contract Net protocol has seen a great deal of use in the agent-based supply chain management literature. Sandholm [11] is one such paper, which details an agent-based delivery routing model based on a generalisation of the Contract Net protocol, implementing a formal model for task announcing, bidding and awarding decisions. In the supply chain reconfiguration literature, Tranouvez and Ferrarini [12] proposes a cooperative reconfiguration technique based upon distributed problem solving, in a similar manner to the Contract Net approach, for disruption management in supply chains. Giannikis and Louis [13] adopts a different approach, using a supply chain event management module, in conjunction with modules to coordinate production and risk management, in order to coordinate the reconfiguration of disrupted supply chains in a centralised, non-distributed manner.

The following sections will describe our multi-agent system model and how we propose to use it to model a functioning supply chain network.

## **AGENT-BASED SUPPLY CHAIN LOGISTICS NETWORK MODEL**

Our model consists of a three-tier manufacturing supply chain network made up of a collection of autonomous agents representing suppliers, manufacturers and retailers. These agents conduct and coordinate the production and logistics operations which make up the supply chain. We assume that suppliers and manufacturers operate according to a just-in-time strategy.

### **Supplier Agents**

The first tier of the supply chain is composed of multiple supplier agents. Each supplier agent is able to produce a single type of precursor good. These agents supply precursor items of the required types and quantities to manufacturer agents in the second tier of

the supply chain. In order to deliver goods, supplier agents have at their disposal a limited fleet of trucks with finite, homogeneous capacities. Supplier agents are linked to manufacturer agents by roads of various lengths. Trucks incur a cost proportional to the total distance they travel in delivering goods. Supplier agents maintain a list of planned production which specifies, for each time step of the simulation, the types and number of units of goods to be produced. They also maintain a list of planned deliveries. Each entry in this list contains information about the type of good to be delivered, the truck to be used, the expected time of despatch, the expected time of delivery and the expected return time of the truck.

### **Manufacturer Agents**

The second supply chain tier is composed of manufacturer agents. Each manufacturer agent is capable of producing a subset of a greater subset of possible manufacturable goods at any one time. Manufacturers rely on deliveries from suppliers in order to produce their outputs, and must acquire precursor goods of the necessary types and quantities in order to be able to produce their outputs. Manufacturers supply retailer agents with manufactured goods of the desired types and quantities. Similar to suppliers, manufacturer agents deliver goods to retailers using a limited fleet of trucks. Manufacturers are linked to suppliers and retailers by roads of varying lengths. Again, trucks incur a cost proportional to the total distance they travel in delivering goods to retailers. As with supplier agents, manufacturer agents maintain a list of planned production and planned deliveries.

### **Retailer Agents**

The third and final tier of the supply chain is made up of retailer agents, who send to manufacturers requests for goods in specified quantities. Retailers assign a delivery deadline for each of their desired goods: manufacturers who miss a deadline are charged a lateness penalty. If any deliveries still remain incomplete by the end of the simulated day, an additional cancelled delivery charge is applied. As the final tier in the proposed model, we do not model the onward logistics operations of retailer agents.

### **Trucks and Goods**

As previously mentioned, supplier agents and manufacturer agents each possess a limited fleet of trucks, with limited homogeneous capacities. For the purposes of simplicity, we assume that goods are produced in truckloads (denoted as  $tl$ ) by suppliers and manufacturers, and that each truck can carry  $1tl$  at any one time.

### **Modelling RFID and Barcode-based Track and Trace**

In order to gauge the effectiveness of RFID as a means for facilitating supply chain reconfiguration, we include functionality to model the properties of an RFID-enabled track and trace system within the supply chain logistics network our model represents. To provide a means for comparison, we also include functionality to model a barcode-based track and trace system.

### **RFID-based Track and Trace**

Under the RFID-based track and trace system, we attach a small fixed additional cost  $rc$  to each unit of output produced by suppliers and manufacturers. This cost encodes both the cost to the participant of purchasing the tag, plus some small additional per-unit cost

contributing to the running and upkeep of the RFID-based system. To model the benefits of using RFID-based track and trace, supply chain partners are able to reroute trucks instantly and at no additional cost when using the RFID-based system. This allows for faster and potentially more efficient reconfiguration. We use our model to compare the performance of this with alternative functionality which models the use of a barcode-based system. This system is explained in the following subsection.

### **Barcode-based Track and Trace**

Under the barcode-based track and trace system, each unit of output produced incurs no additional cost. This models the relative cheapness of using a barcode-based system in the real world (in comparison to a more expensive RFID-based system). However, when using barcodes, partners face a slight delay in rerouting trucks, which incurs additional costs in terms of total travelling costs and the potential for late deliveries.

## **SUPPLY CHAIN RECONFIGURATION TECHNIQUES**

Once a complete and working supply chain logistics network has been established – this is accomplished using mixed integer programming to produce an efficient initial network - it is necessary for the purposes of our work to introduce a disruption. In a real-world supply chain, the potential cause of such a disruption could be one or more of numerous possibilities. In this study, we model a situation in which the scheduled production of a manufacturer is disrupted due to a manufacturing fault. This is modelled by removing the ability of a randomly chosen manufacturer the ability to produce one of the goods it currently plans to produce. The following subsections describe the two reconfiguration techniques we propose to allow the agents within the supply chain to deal with this disruption.

### **Low Communication Reconfiguration Technique**

Our first proposed reconfiguration technique is for supply chain networks in which levels of communication and collaboration between participants are relatively low. This brings about challenges in terms of producing efficiently-reconfigured networks. Because of the potentially inefficient solutions which may be generated in situations with low levels of communication and collaboration, any efficiency savings which can be made are extremely valuable. This makes low-communication scenarios an extremely important domain in which to test the relative benefits of RFID and barcodes in terms of efficiency and cost savings. The low communication reconfiguration technique is a local optimisation algorithm used by supply chain agents which reconfigures their current production and deliveries as well as their future production and delivery plans. We explain how the algorithm works in the following paragraphs.

### **Step One**

When the affected manufacturer detects a disruption, it examines its future production plans and produces a list of the goods it is no longer able to produce and the number of units affected. It removes planned production and delivery of the affected goods.

## Step Two

For each of these goods, the manufacturer first attempts to find other manufacturers currently producing the good in question with available capacity. These manufacturers are given precedence so that retooling may be avoided and  $a_{rc}$  minimised. Priority within this set of manufacturers is given to those who are closest to a supplier which produces the precursor to the good in question so that  $t_d$  is kept to a minimum. If any of the manufacturers within the network fit this description, they claim as many units of the good as they are able to produce. Once the capacities of all manufacturers currently producing the good(s) in question are exhausted, priority is given to manufacturers who are not currently producing the good but who have excess capacity and are able to produce the good in question without retooling. Again, within this set of manufacturers, those who are closest to the supplier of the relevant precursor good are given priority. Once the claims from this set of manufacturers have been made, if a shortfall still remains then, as a last resort, manufacturers who need to retool in order to produce the remaining units of the good are surveyed. If any shortfall remains after all available manufacturers have been surveyed, we regard it as a cancelled delivery and add a cancellation fee  $cd_c$  for each unit cancelled to the total reconfiguration cost.

## Step Three

Each of the manufacturers who claimed additional or alternative units of production inform the suppliers of the relevant precursor goods, who update their production and delivery schedules accordingly and inform the affected manufacturers.

## HIGH COMMUNICATION RECONFIGURATION TECHNIQUE

Our second proposed supply chain reconfiguration technique is for supply chain networks where the amount of communication between partners is relatively high. This technique is based upon an implementation of the Contract Net protocol, and works as follows:

### Step One

An agent within the supply chain network designates itself as the "initiator". This agent is, in the first instance, the manufacturer at which production has been affected. This agent sends out a call for proposals to all other agents specifying the types and quantities of goods that need to be produced for the network to function as it had been in its pre-disruption state. The other agents then examine the call for proposals to decide whether they are able to fulfil the requirements of the call.

### Step Two

Each agent able to satisfy the requirements of the call for proposals submits an offer to the initiator agent. Each offer specifies the total additional cost to the network of the offering agent being awarded the contract. These costs may include additional transport costs  $t_d$  and retooling costs  $a_{rc}$ . If no offers are made, the system returns to Step One and the initiator breaks up the original call for proposal into two (or more, if more than

one rounds of no offers have been encountered) calls for proposals which require fewer units of the requested good. Otherwise, the offer incurring the least cost is chosen by the initiator and the system proceeds to the next step.

### Step Three

The role of initiator shifts to the agent whose contract was accepted by the original initiator. In the first instance, this is typically a manufacturer agent who has committed to supply one or more goods to retailers that it was not originally planning to produce. In order to obtain the necessary precursor goods for these newly-planned outputs, it submits a new call for proposals requesting the required precursor goods in the necessary quantities.

### Step Four

As in Step Two, each agent inspects the call for proposals and decides if it is able to fulfil the requirements. As before, agents able to meet the specification of the call submit offers to the initiator specifying the total additional cost, and the initiator chooses the one with the lowest cost and transmits the acceptance of the offer to the other agents. Again, if at this point no offers are received then the initiator splits the call for proposals into multiple calls requesting fewer units, and the process continues as planned.

### Step Five

Once the shortfall of goods caused by the disruption has been dealt with, the process of calling for proposals and offering closes. All agents update their production and delivery plans to take into account the results of the reconfiguration.

### COST FUNCTION

The aim of any reconfiguration technique to be applied to this model is to minimise the cost function given below:

$$Cost = \sum_{t \in T} t_d + \sum_{a \in A} a_{rc} + ld_t ld_c + cd_t cd_c$$

Where  $t$  is a truck in the set of all trucks  $T$  in the model.  $t_d$  is the total cost of the distance travelled by truck  $t$ .  $a$  is a single agent in the set of all agents  $A$ .  $a_{rc}$  is the total retooling cost incurred by agent  $a$ .  $ld_t$  is the total number of late deliveries and  $ld_c$  is the charge applied to each late delivery. Finally,  $cd_t$  is the total number of cancelled deliveries and  $cd_c$  is the charge applied to each cancelled delivery.



## EXPERIMENTS

We performed three sets of experiments, each of which aimed to test the relative performance of RFID and barcode-based systems in our model under varying conditions. The details of each experiment are provided in the following subsections. For all experiments, we assume the following constants: suppliers and retailers are able to produce 1 unit of output per time step; trucks travel 1 unit of distance per time step and incur a cost of 1 per unit of distance travelled; distances between each participant are drawn randomly from the interval [1...10]; under barcodes retooling incurs a cost of 5 and takes 3 time steps to complete while rerouting takes 3 time steps to complete; finally, each unit of each good produced under RFID incurs a cost of 0.01. Unless otherwise stated, we also assume that the disruption occurs at time step 3 and the number of suppliers, producers and retailers are fixed at 10 for each type of agent.

### Network Size

In this series of experiments, we tested the performance of RFID and barcodes in supply chain networks of varying sizes. Specifically, these experiments were conducted in *small*, *medium* and *large*-sized networks. For these experiments, the number of suppliers, manufacturers and retailers were randomly and independently drawn from the interval [1...5] for small network experiments, from [5...10] for medium sized networks and from [10...20] for large network experiments.

### Fleet Size

This group of experiments aimed to test the performance of RFID and barcodes in networks where suppliers and manufacturers have varying numbers of trucks at their disposal. Experiments were conducted with *small*, *medium* and *large* fleet sizes, where fleet sizes for suppliers and manufacturers are equal to 5, 10 and 20 respectively. These experiments were conducted with the aim of assessing the effect that shortages or surpluses of transportation vehicles have on the relative performance of RFID and barcodes.

### Disruption Time

This set of experiments seeks to test the performance of RFID and barcodes when disruptions occur at different points in the delivery process. We conducted experiments where disruptions happened at time steps of  $t=2$ ,  $t=4$  and  $t=6$ . At higher time steps, we can generally assume that more vehicles will be in transit, leading to a greater need for rerouting of delivery vehicles but, due to more goods already having been produced, a corresponding smaller need for retooling at the manufacturer level.

For each experiment we performed 100 runs each of barcodes under local reconfiguration, barcodes under global reconfiguration, RFID under local reconfiguration and RFID under global reconfiguration.

## RESULTS

Table 1 presents the results of each set of simulations. To produce a final cost and distance travelled figure for each set of results, we calculated the average cost and average units of distance travelled over the 100 runs performed.

**Table 1. Results produced by barcodes and RFID under low communication (LC) and high communication (HC) reconfiguration for each scenario.**

	<b>LC, Barcodes</b>	<b>LC, RFID</b>	<b>HC, Barcodes</b>	<b>HC, RFID</b>
<b>Small Network Size</b>	Cost: 220.74 Distance: 104.69	Cost: 211.21 Distance: 101.51	Cost 184.98 Distance: 95.88	Cost: 181.6 Distance: 92.62
<b>Medium Network Size</b>	Cost: 501.07 Distance: 390.32	Cost: 492.33 Distance: 387.02	Cost: 466.19 Distance: 381.49	Cost: 463.36 Distance: 378.01

<b>Large Network Size</b>	Cost: 875.7 Distance: 760.45	Cost: 869.18 Distance: 756.64	Cost: 831.52 Distance: 748.52	Cost: 828.66 Distance: 744.74
<b>Small Fleet Size</b>	Cost: 588.01 Distance: 448.91	Cost: 577.32 Distance: 445.43	Cost: 561.54 Distance: 437.84	Cost: 555.29 Distance: 434.36
<b>Medium Fleet Size</b>	Cost: 551.91 Distance: 448.91	Cost: 542.12 Distance: 445.43	Cost: 521.99 Distance: 437.84	Cost: 519.24 Distance: 434.36
<b>Large Fleet Size</b>	Cost: 546.81 Distance: 448.91	Cost: 537.17 Distance: 445.43	Cost: 517.84 Distance: 437.84	Cost: 515.14 Distance: 434.36
<b>Disruption at Step 2</b>	Cost: 539.61 Distance: 447.31	Cost: 535.89 Distance: 445.45	Cost: 519.79 Distance: 440.24	Cost: 518.57 Distance: 438.38
<b>Disruption at Step 4</b>	Cost: 563.24 Distance:451.44	Cost: 547.83 Distance: 446.79	Cost: 524.75 Distance: 437.7	Cost: 520.83 Distance: 433.05
<b>Disruption at Step 6</b>	Cost: 587.71 Distance: 457.06	Cost: 564.45 Distance: 450.76	Cost: 538.3 Distance: 439.3	Cost: 532.79 Distance: 433.02

From Table 1 we see that, as expected, the high-communication reconfiguration technique (HC) produces better results in terms of cost and distance travelled than the low-communication technique (LC) in all experiments conducted. We also see that RFID outperforms barcodes, both in terms of cost and distance, over all experiments. For most experiments, RFID performs proportionally better cost-wise compared to barcodes under LC than under HC. We suggest that this is likely to be because LC's struggles in terms of finding an optimal reconfiguration of production and deliveries are offset by the faster reconfiguration afforded by RFID. On the other hand, under the better-performing HC technique, faster reconfiguration offers correspondingly smaller cost savings because reconfiguration is performed more accurately. Of particular interest are the disruption time experiments: we see that when a disruption occurs early, the difference in performance between barcodes and RFID is quite small. However, as the disruption step becomes later, the gap in performance between the two technologies widens. This may be because more trucks are likely to be on the road as the disruption time becomes later, requiring a larger amount of rerouting. RFID allows this rerouting to be performed more quickly than barcodes, reducing the number of late deliveries.

## SUMMARY

In the paper, we have proposed a multi-agent system of a supply chain network, in which each member of the supply chain is represented by an individual autonomous computational agent. We have presented two different techniques which may be used to reconfigure the network when a disruption occurs – a myopic local reconfiguration technique which models supply chain networks with low levels of communication and collaboration between partners, and a Contract Net-based reconfiguration method which models networks with greater levels of collaboration and communication. Within the context of our model, we also proposed a way to model the use of barcodes and RFID technology by supply chain participants, and described how the use of these technologies within our model impacts upon the reconfiguration process in terms of the potential for time savings and cost reductions.

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## **Section 12 – Sustainability in Logistics and Supply Chains**

### **SHARED LOGISTICS RESOURCES – WIDENING AND BROADENING THE CONCEPT OF COMMON POOL RESOURCES FOR LOGISTICS**

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#### **ABSTRACT**

#### **INTRODUCTION**

Logistics is responsible for all value creating and auxiliary processes to achieve a spatial and temporal balance between demanded products and provided products. Due to the high degree of labor share it is necessary to transport goods over long distances from production sites to markets. The trend towards low price products requires intensive storage of finished (or semi-finished) products until the product is requested from the market realizing economies of scale by largest lots in production.

During the last decades, production efficiency has been improved so that the available quantities often exceed the requested quantities. However, product shortages and/or shortages expectations are detected with increasing frequency. Since the quantities are available (produced) it can be concluded that this shortage happens during the distribution stage in a value creation chain. Thus, the product shortage is identified to be related to the logistics activities in a value creation chain.

Logistics faces obvious resource scarceness problems that become visible immediately. Traffic jams indicate that the specific resource "road" is scarce or even partly exhausted at certain times. The resulting congestion prolong transfer times to the next transshipment terminal and late arrivals there causes additional delays in the material flow since the transshipment facilities are already blocked and so on. Short local process disruptions finally result in process delays spread over whole value creation networks. On the other hand and in contrast to the aforementioned resource scarceness there are unused resources like semi-filled trucks that maintain unused capacities which cannot be exploited by the operators.

Although it is obvious that logistics requires managing this resource scarceness, it remains unclear at first glance why this scarceness appears more often in today's economic system settings. It is indisputable that the growing resource scarceness endangers the performance of logistics in modern societies. Finally, a performance decrease of logistics can negatively affect the economic prosperity and growth of our society. It is for this reason that we need to understand the underlying reasons for the observed scarceness of resources in logistics propose strategies to overcome this menace.

This paper reports initial research results related to the aforementioned phenomena of scarceness of resources related to logistics. The here reported research aims at identifying the major reasons and drivers for the increasing frequency of scarceness situations in logistics processes and value creation systems. A primary goal of the conducted research is to understand the mechanisms that finally lead to the observed

resource shortage. Adequate countermeasures are proposed in order to sustainably preserve the currently high performance of the logistics sector.

This manuscript addresses the following research questions:

- What are the underlying trends in the market conditions for the logistics sector that contribute to the observed scarceness of resources needed for logistics processes?
- 1. What are the longer term impacts of the ongoing trend to keep resources as scarce as possible as a result of the involvement of private investors in the provision of formerly general public resources

### **FROM DEMAND- TO BOTTLENECK-ORIENTATION – THE MICROECONOMIC PERSPECTIVE OF RESOURCE SCARCENESS**

We use the general definition of a resource given by Wernerfeldt (1984) who characterizes a resource to be anything that can be taken as a strength or a weakness of an organization. If these resources contribute to the realization of logistics services, we understand them as logistics resources. While in the past, massive investments have been directed into the set up work and extension of production systems, logistics services have been assigned as auxiliary functions for the support of production systems. Furthermore, modern value creation systems assume that logistics services like transport and storage are always available at rather low costs. As a consequence, providers of logistics services are expected to adjust their maintained resource capacities to the demand that is mainly triggered and determined by the output realized from the production part of a value creation process. However, recent economic trends lead to scarceness of logistics resources which contradicts the underlying assumption that logistics services are available at unlimited capacity whenever needed at quite low costs.

External impacts leading to reductions of the production output or to a significant increase of the produced quantities appear frequently. To hedge the performance of logistics systems against these workload variations, providers of logistics resources try to adjust their resources to the demand in order to preserve their market position (demand orientation of logistics resources). In situations where the workload is increased, resources are in danger to be exhausted causing additional costs like overtime hour surcharges. In situations of decreasing demand, parts of the resources remain unproductive. Since logistics activities are (still today) considered often as support functions it is hardly possible to cover the additional expenses related to resource adjustments to the leading customers from production. Thus, providers of logistics services try to increase the efficiency of the available resources but this strategy starts to fail because human resources as well as technical resources are reaching their natural performance limits. Workload peaks cannot be managed anymore so that temporary resource scarceness appears.

These observations can be supported by the following market trends:

- Continued deregulation of markets (regulatory politics): Access to logistics-relevant infrastructures like transportation systems of road, track and water has been regulated by national laws for several decades because each national government wanted to protect the national value creation. Also military needs played an important role in the protection and regulation of access to national infrastructures. In this context, infrastructures have been provided and maintained by the national government and national providers of logistics services were granted exclusive access to these infrastructures. No explicit access costs must be paid by the users from the logistics sector. Prices for logistics services were not determined on the market but regulated by national law. Access to national infrastructures is now possible to logistics service providers from other

member states. Existing imbalances of labor costs and prices are used by foreign logistic service providers to enter so far closed markets and to gain significant market shares. Often the pressure exerted on prices cut down profits of logistics service providers who have operated profitable before. Often, sustainable price reductions for logistics services have been established as a result of deregulation (Aberle, 2009). The deregulation of access to logistics-affine infrastructure finally leads to reduced profits so that providers of logistics services must manage their resources more carefully. Inefficient usage of resources must be prevented in order to ensure the survival of companies from the logistics sector. Consequently, these companies hesitate to extent the capacity of their resources if load peaks appear if this is somehow possible. The demand for transport and other logistics services is still increasing so that such a behavior finally leads to scarceness of the maintained resources in workload peak situations.

- Increasing prices for energy consumption and emissions (energy politics): The fulfillment of fragmented and geographically distributed customer demand requires excessive transportation (e.g. case of Amazon, Ebay, and Dell). The ongoing penetration of these transport-oriented distribution concepts finally leads to an increase and intensification of logistics services, which accounts for 10%-15% of the overall product-related costs (Mantzios et al., 2003). The intensification of transportation implies an increase of the consumed energy. In EU27, the logistics sector reveals a very high amount of consumed energy (European Commission, 2010) which is expected to growth further. Transportation contributes the largest part of the overall energy consumption within this sector. Fossil energy is limited and the peak-oil, which indicates the beginning of fossil energy scarceness, is expected to be reached already so that the price for fossil energy starts climbing up.
- Increasing pressur for internalization of external costs (fiscal policy): It has been decided at the beginning of the 20th century that investments into infrastructure were of public interest. The production sector did not contribute to the installation and maintenance of today's infrastructure. Therefore, production-related costs do not include costs for the installation of the distribution system. The internalization of traffic-infrastructure costs was not intended (with the exception of the civil air transportation). The possibility to ignore any infrastructure-related costs in product-prize calculations has led to an often global segmentation of production and value creation processes within the last seven decades. Value creation chains are global today exploiting least labor costs at different regions of the world. During the last two decades the extent of public funding that is directed to the extension and maintenance of infrastructures has been cut down in most European countries. Some countries (e.g. Germany) started to take money for the usage of major roads. Other countries extend the involvement of private investors into the installation and renovation of critical infrastructure components like tunnels or bridges. Often, the access to these infrastructures requires the payment of a certain fee. Since taxes are not reduced, the costs for the execution of transportation processes raise up so that so far external costs for infrastructure provision is partially internalized. The increase of the amount of energy consumed by the logistics sector is accompanied by a continuous extension and intensification of harmful emissions like greenhouse gases and noise (Wie and Tobin, 1998). This happens despite continuous technological innovations and improvements (Aberle, 2009). It is social need and political will to prevent sustainable damage of the ecological system and the limitation of the overall amount of emissions is enforced by regulations and laws. The application of the concept of emission right trading is the most important tool to limit the overall amount of harmful emissions at short hand and to reduce it in the longer perspective (Wie and Tobin, 1998). The need to buy the right to emit harmful substances (or noise) leads to scarce "output resources" since the overall number of emission certificates is limited. The price for the right to emit harmful

substances (or noise) will finally grow up making energy consumption more expensive.

**TRAGEDY OF COMMONS IN LOGISTICS: THE MACROECONOMIC PERSPECTIVE OF RESSOURCE SCARCENESS IN THE LOGISTICS SECTOR**

Over long periods societies are frequently faced with situations in which important resources become scarce. Periods of dryness are typically followed by periods of starvation. Also manmade shortages are observed, e.g. overfishing of the oceans and over-fertilization that result in slow extension of crop failures. Especially with respect to man-made (anthropogenic) scarceness it has been shown that the shortage is the result of a long lasting and uncontrolled usage of resources that originally were not scarce but nobody felt responsible to take care for such a resource because the considered resource has had no explicit owner. Such a resource is called a "common-pool resource" (CPR) in macroeconomics (Ostrom, 2008) and the descent of common pool resources due to overstress by uncontrolled access to such a resource is discussed as the "tragedy of the commons" (Hardin, 1968).

We classify logistics resources into three categories: environmental resources, infrastructure resources and private resources. The ownership associated with resources from each category as well as the responsibilities of funding for the installation and maintenance of the resources are shown in Figure 1.

resource category	ownership	funding	access
environmental (e.g. air, water)	general public	---	uncontrolled
infrastructure (networks for transport or communication, security and emergency services)	general public of a nation	public sources	almost uncontrolled
private (e.g. supra-structures and/or mobile resources)	private	private investors	controlled

Figure 1: Historically grown responsibilities for the provision of logistics resources.

Environmental resources have no owner in the legal sense. In the past, no funding was directed to resources of this kind. Infrastructure resources are setup and maintained by public source funding and have been owned by the general public of a nation (the funding came of taxes and other duties of the national citizens). These two categories of resources were accessible for all potential users. There had been no explicit access and consumption control. Private resources have had an explicit owner who is responsible for the funding of the installation and maintenance of its resource. This owner has to right to grant or deny access to its resources.

Obviously, private investors want to gain profits with the resources they provide. Therefore, it is reasonable that they control access to their resources effectively in order to assign access rights to those users who are willing to pay the maximal compensation for the resource consumption. Furthermore, it is reasonable to assume that capacity of private resources tends to be scarce since the private investors assume a limited demand for the usage of the capacity of their resources. In case that the actual demand exceeds the forecasted demand, potential users will be in competition for the access to these resources. The control of access to CPRs is possible but often quite expensive so that it is not reasonable to define a connection between the usage and payment of resource

utilization for a certain transaction. CPRs have been investigated in depth in the context of a sustainable management of socioeconomic systems. Examples for analyzed CPRs are the management of water systems and fishery areas (Ostrom, 2008) as well as drinking water reservoirs (Künneke and Finger, 2009) and forests. All these investigations have been motivated by the need to overcome an already happened or expected shortage of resources as a result of uncontrolled and myopic consumption of originally rich resources. The recent situation of the environmental and infrastructure resources required by the logistics sector is similar and these two resources can be interpreted as CPRs (different users compete for the capacity of these resources and access control to these resources is very costly).

Since we have found out that environmental as well as infrastructure resources have transformed from formerly unrestricted resources to CPR it is reasonable to establish a connection between the shortages of these logistics resources with the shortages of other CPRs. The terminal point of this progress is referred to as "tragedy of the commons" (Hardin, 1968). As soon as this point is reached the considered resources are irreversibly destroyed. As is has been mentioned before, previous investigations have developed strategies to stop the process of CPR shortage effectively. The major innovation was to assign owner(s) to those resources that are endangered and to obligate and reward a new owner for establishing a resource management that makes the resource utilization sustainable (Altrichter and Basurto, 2008). Such a resource protection is mainly based on effective access control to the endangered resources (the CPRs).

The installation of resource control systems must be comprehensive for all resources. With respect to environmental resources as well as infrastructures first steps in this direction can be found that affects the logistics sector. First, most of the European countries have installed access control systems to major road connections. So far, the major motivation for detecting infrastructure is to get tolls for the infrastructure usage. Access blockages are currently not subject of discussion. However, the access can be balanced over time by setting quite high tolls during travel peak times. The determination of property rights is motivated by the implication that owners of a resource have an intrinsic interest for the sustainable management of their property.

Public-private-partnerships (Gerstlberger and Schneider, 2008) which are recently used e.g. in the extension of the German highway network are an example in which the ownership of an infrastructure is transferred from general public to private investors. Here, access control to the motorways are used to gain tolls from automobilists and the private investors get a portion of the overall sum of collected tolls as long as they maintain their property in a shape that has been agreed with the government. If the resource cannot be used as expected due to damage or inappropriate winter services, the transferred sum of collected tolls from the government to the private investor is reduced. This gives motivation for the private investor to maintain the setup infrastructure and to keep it in a good shape.

The second concept for the installation of access control for CPR does not require any transfer of ownerships to private partners. Instead, access is completely blocked to give the resource time to recover (e.g. environmental resources). It is also possible that the governmental organizations specify a toll for using public resources with the goal to install a market-based regulation of access to a scarce resource. This market-based assignment of utilization opportunities for a scarce resource enables an access control to public resources that does not need an active role of the government during the assignment of utilization rights. Although the control of access to infrastructure and environmental resources has not a long tradition, the installation of mechanisms for access control has already led to a shift in the responsibilities for the provision of logistics resources.



Figure 2 shows the recent ownerships of the three resource types as well as the updated funding responsibility and also information about the applied access control. Recently established modifications of historically grown responsibilities compared to the assignments given in Figure 1 are printed in bold.

resource category	ownership	funding	access
environmental (e.g. air, water)	general public	<b>public sources and private investors (A)</b>	<b>controlled (B)</b>
infrastructure (networks for transport or communication, security and emergency services)	general public of a nation <b>and private investors (C)</b>	public sources <b>and private investors (D)</b>	<b>controlled (E)</b>
private (e.g. supra-structures or mobile resources)	private	private investors	controlled

Figure 2: Shifted responsibilities for the provision of logistics resources. (A) = funding is now directed to the recovery and protection of environmental resources and comes from governmental organizations as well as from private investors (e.g. via revenues from emission certificates); B = control of the access to environmental resources is applied (e.g. by restricting emissions to quantities covered by acquired certificates); (C) = private companies are now allowed to become owners of infrastructures resources (e.g. via public-private-partnerships for infrastructure projects); (D) = private companies participate in the funding of infrastructure resources; (E) = access to infrastructure is subject of control for determination of usage tolls as well as blocking or limiting the access.

The responsibilities for the provision and funding of infrastructure resources as well as for the utilization of environmental resources have been re-configured recently. Private investments into infrastructure resources are made. Control of access to so far unlimited resources is effective now.

**CONCLUSION AND OUTLOOK**

In this paper, we discussed our initially stated research questions concerning the analysis of the performance of the logistics sector in the future. Regulatory politics, measurements of energy politics as well as the pressure to reduce public funding of infrastructure projects affect logistics. Situations, in which logistics resources become scarce or unavailable, are detected more frequently. The reduction of the general public funding in infrastructure is accompanied by increasing private investments in infrastructure resources. The capacity of private funded infrastructure resources is adjusted to carefully estimated future demand quantities. Thus, such resources are potentially scarce.

In the longer term context it is necessary to equip the logistics sector with tools to manage frequently appearing resource scarceness. We have proposed to install business models based on so-called "shared resources" for the logistics sector. Shared resources are cooperatively managed by two or more independent partners. The interchange of information about available capacities as well as demand to be fulfilled contributes to the maximization of the efficiency of the available resources. Imbalances between demanded and available capacity volume are reduced. Although there are some applications in the logistics sector applying successfully a cooperative resource management basic impacts, potentials and mechanism of the common management of resources require basic and fundamental research.

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# COORDINATING A SUPPLY CHAIN WITH A HETEROGENEOUS VEHICLE FLEET UNDER GREENHOUSE GAS EMISSIONS

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## ABSTRACT

This paper studies a supply chain consisting of multiple suppliers and a single buyer. Products that are delivered from the suppliers to the buyer are collected in one or more milk runs to reduce the overall number of deliveries between the suppliers and the buyer. For collecting the products, the buyer operates a fleet of heterogeneous vehicles, where each vehicle type has its own characteristics with respect to carrying capacity and fuel consumption. By assigning different vehicles to different milk runs, and by coordinating production and consumption in the system, the buyer may reduce inventory-related cost and lower greenhouse gas emissions that are generated in the supply chain. This paper develops a mathematical model of a multiple-supplier-single-buyer supply chain and integrates technical characteristics of different vehicle types into the model. It then studies the impact of production, consumption and transportation on the total cost of the supply chain and on the greenhouse gas emissions generated in transportation. The behaviour of the model is illustrated using numerical examples.

## INTRODUCTION

In recent years, there has been a growing interest in the role of the manufacturing and logistics sector in achieving global sustainability (e.g., Sarkis, 2001). Sustainability programmes implemented by corporations have been complemented by legal initiatives, such as the introduction of the European Union Emission Trading System or CO<sub>2</sub> taxes that are raised in several European countries (Jaber et al., 2013). The objective of sustainability initiatives typically is to address the "triple bottom line" of corporate economic, environmental, and social performance (Elkington, 1997), which includes the reduction of CO<sub>2</sub> emissions.

It is clear that the operating policies implemented in a supply chain are a critical determinant of the amount of greenhouse gas emissions generated in the supply chain. Frequent shipments, the production of defective items and the operation of machines outside of their design production rates are just three examples of operating policies that may contribute to higher levels of CO<sub>2</sub> emissions than necessary that result from production.

A closer look at the literature shows that prior research on the coordination of production and consumption in supply chains had a primary focus on the reduction of operating costs (Glock, 2012a). Despite a stream of research that studies the production of defective items in supply chains (e.g., Affisco et al., 2002; Huang, 2002), only a few works exist that analysed the environmental impact of lot sizing decisions from a systems perspective (cf. Jaber et al., 2013).

The aim of this paper is to develop a mathematical model of a multiple-supplier-single-buyer supply chain and to study the impact of lot sizing decisions on the cost of the supply chain and the amount of greenhouse gas emissions generated in the chain. The focus of the paper is on CO<sub>2</sub> emissions that result from transporting products within the supply chain, although it is clear that other sources of greenhouse gas emissions may exist in the supply chain. This paper further contributes to the literature by investigating

a joint economic lot size model with multiple suppliers, which have thus far only infrequently been analysed (e.g., Kim and Goyal, 2009; Glock, 2012b).

The remainder of the paper is organised as follows. The next section describes the problem studied in this paper, and Section 3 develops a mathematical model of a multiple-supplier-single-buyer supply chain. Section 4 contains numerical examples, and Section 5 concludes the paper.

### PROBLEM DESCRIPTION

As stated earlier, this paper studies a supply chain consisting of multiple suppliers supplying a product to a single buyer. The paper assumes that in addition to the lot-sizing problem, a routing plan among the suppliers has to be determined. The problem studied in this paper is illustrated in Figure 1. As can be seen, suppliers ( $S_i$ ) are assigned to different supplier groups, which are then served by different vehicles.

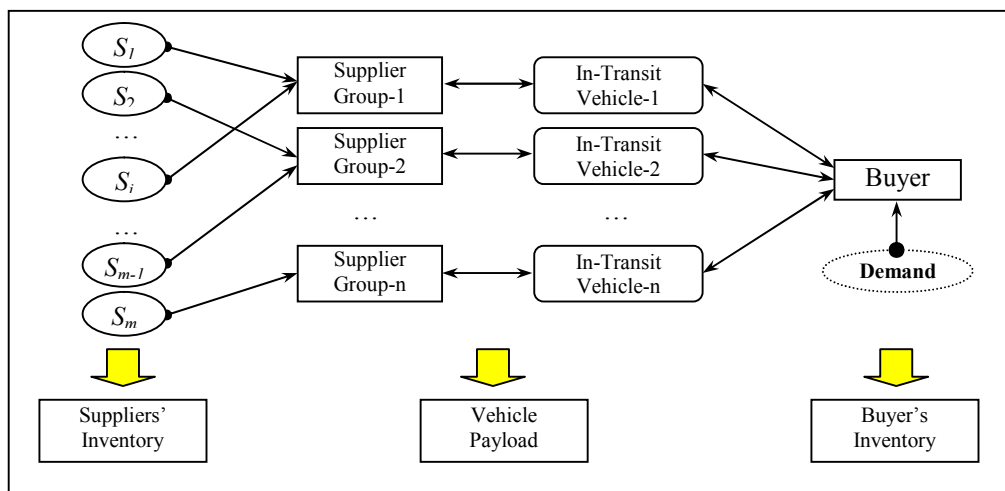


Figure 1. Illustration of vehicle operations in a multiple-vendor single-buyer supply chain

Hereafter, we use the following set of notations in developing the proposed model:

#### Definitions:

- $m$  : number of suppliers
- $n$  : number of heterogeneous vehicles (or equivalently: routes)
- $i, j$  : indices for suppliers
- $k$  : index for a vehicle
- $R$  : set of heterogeneous vehicles (or routes), where  $R = \{R_k | 1 \leq k \leq n\}$

#### For the buyer

- $A$  : order processing cost
- $h_b$  : inventory holding cost
- $D$  : annual demand rate

#### For supplier $i$ :

- $S_i$  : production set-up cost
- $h_i$  : inventory holding cost
- $P_i$  : annual production rate

#### For vehicle $k$ :

- $a_k$  : vehicle loading capacity
- $v_k$  : vehicle velocity
- $c_k$  : vehicle operating cost per unit time (routing cost)
- $e_k$  : CO<sub>2</sub> emission cost per unit payload per unit time (emission cost)

- $R_k$  : set of suppliers visited by vehicle  $k$ , where  $R_k \cap R_{k'} = \emptyset$  if  $k \neq k'$
- $d_k$  : length of route  $k$
- $\tau_k$  : time to complete route  $k$  if vehicle  $k$  is used for this route
- $\rho_k$  : time-weighted payload if vehicle  $k$  is used for this route
- $B_k$  : lot size delivered by vehicle  $k$ , where  $B_k = \sum_{i \in R_k} q_i$

*Routing-related parameters:*

- $d_{[i],[i+1]}$  : travel distance between the  $i$ th and the  $(i+1)$ th supplier. The bracket symbol in the subscript represents the index for the sequence in a route. The index value for a buyer is set as 0.
- $t_{[i],[i+1]}^k$  : travel time between the  $i$ th and the  $(i+1)$ th supplier if vehicle  $k$  is used. The bracket symbol in the subscript represents the index for  $i$ th supplier in a route. In addition, the index value for a buyer is set as 0.

*Decision variables:*

- $T$  : common cycle length for the suppliers and the buyer
- $Q$  : order quantity of the buyer, where  $Q = DT$
- $\pi_i$  : lot allocation rate for supplier  $i$ , where  $\sum_{i=1}^m \pi_i = 1$
- $q_i$  : production-delivery lot-size of supplier  $i$ , where  $q_i = \pi_i Q$   $1 \leq i \leq m$
- $Z_k$  : routing sequence of vehicle  $k$
- $x_{ij}^k$  : binary variable which indicates whether the vehicle  $k$  travels from supplier  $i$  to supplier  $j$
- $U_i^k$  : cumulative loading quantity of vehicle  $k$  up to supplier  $i$

The typical inventory patterns for both suppliers and a buyer are illustrated in Figure 2.

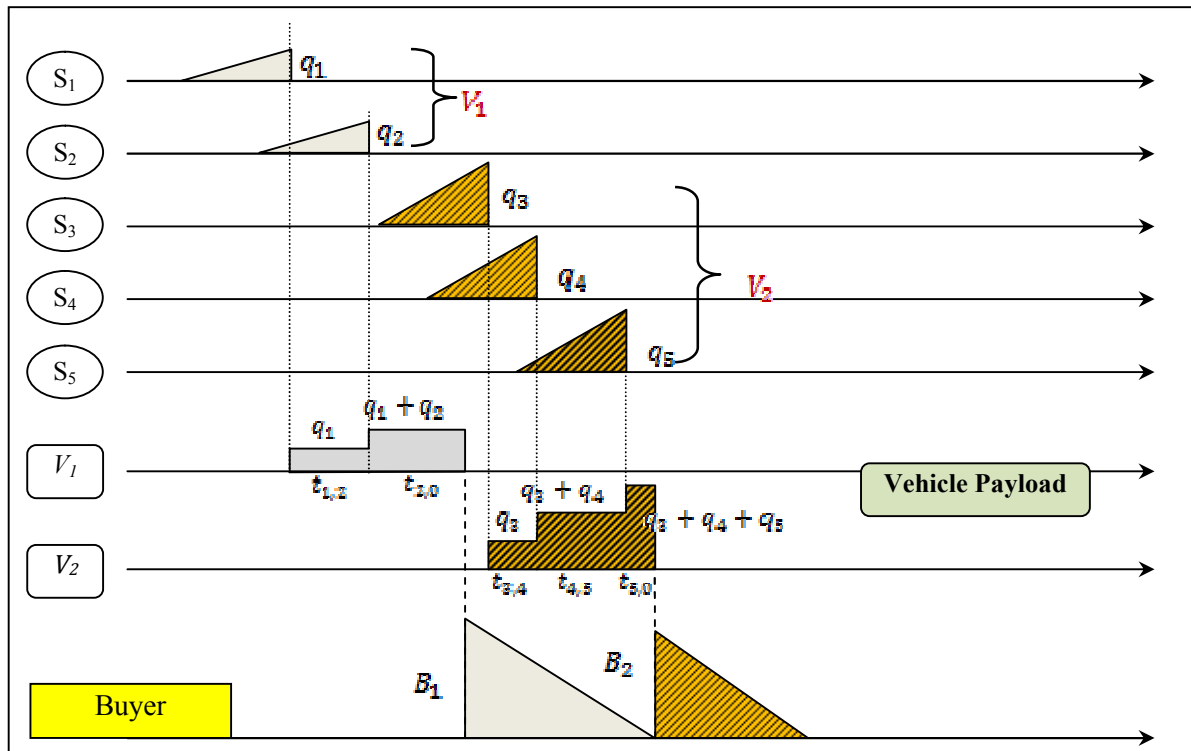


Figure 2. Typical inventory patterns in a multi-supplier-single-buyer supply chain

**MATHEMATICAL MODEL**

The total relevant cost can be formulated as a function of cycle length, delivery lot-size, and routing plan by considering the cost of both suppliers and the buyer and by including the material in-transit by vehicles as seen below:

**Minimise**

$$TRC(T, q, Z) = \frac{\sum_{i=1}^m \left( S_i + \frac{h_i q_i^2}{2F_i} \right) + \sum_{k=1}^n (c_k \tau_k + e_k \rho_k) + \left( A + h_b \sum_{k=1}^n \frac{Q_k^2}{2D} \right)}{T} \quad (1)$$

, where

$$\tau_k = \sum_{i=0}^{|R_k|-1} t_{[i],[i+1]}^k, \text{ where } t_{[i],[i+1]}^k = \frac{a_{[i],[i+1]}^k}{v_k}$$

$$\rho_k = \sum_{i=1}^{|R_k|-1} t_{[i],[i+1]}^k \sum_{j=1}^i q_{[j]} + t_{[|R_k|],0}^k \sum_{j=1}^{|R_k|} q_{[j]} = \sum_{j=1}^{|R_k|} q_{[j]} \sum_{i=j}^{|R_k|} t_{[i],[i+1]}^k$$

, where  $[0] = [|R_k| + 1] = 0$

The transportation cost in Eq. (1),  $\sum_{k=1}^n (c_k \tau_k + e_k \rho_k)$ , are calculated with reference to Kopfer et al. (2012), and they consist of the sum of vehicle operating cost and emission-related cost.

In addition, by definition, we know that the value of  $q$  is a function of  $T$ . Thus, the above cost function can be re-stated as a function of the lot-allocation policy among the suppliers, i.e., as a function of  $\pi$  instead of  $q$ . Thus, the above equation is re-formulated as:

$$TRC(T, \pi, Z) = \frac{(A + \sum_{i=1}^m S_i) + \sum_{k=1}^n c_k \tau_k}{T} + \frac{D^2 T}{2} \left( \sum_{i=1}^m \frac{h_i \pi_i^2}{F_i} + h_b \sum_{k=1}^n \frac{(\sum_{i \in R_k} \pi_i)^2}{D} \right) + D \sum_{k=1}^n e_k \left( \sum_{j=1}^{|R_k|} \pi_{[j]} \sum_{i=j}^{|R_k|} t_{[i],[i+1]}^k \right) \quad (2)$$

From the above equation, we can derive the optimal cycle length as seen below if the routing schedule is pre-determined as  $Z$ . From the following first-order condition

$$\frac{dTRC(T, \pi, Z)}{dT} = - \frac{(A + \sum_{i=1}^m S_i) + \sum_{k=1}^n c_k \tau_k}{T^2} + \frac{D^2}{2} \left( \sum_{i=1}^m \frac{h_i \pi_i^2}{F_i} + h_b \sum_{k=1}^n \frac{(\sum_{i \in R_k} \pi_i)^2}{D} \right) \quad (3)$$

we can obtain the following stationary point of the cycle length  $T$ :

$$T^0(\pi, Z) = \frac{1}{D} \sqrt{\frac{2(A + \sum_{i=1}^m S_i + \sum_{k=1}^n c_k \tau_k)}{\sum_{i=1}^m \frac{h_i \pi_i^2}{F_i} + h_b \sum_{k=1}^n \frac{(\sum_{i \in R_k} \pi_i)^2}{D}}} \quad (4)$$

By substituting Eq. (4) into Eq. (2), we obtain the following total cost function:

$$TRC(\pi, Z) = D \left( \sqrt{2(A + \sum_{i=1}^m S_i + \sum_{k=1}^n c_k \tau_k)} \left( \sum_{i=1}^m \frac{h_i \pi_i^2}{F_i} + h_b \sum_{k=1}^n \frac{(\sum_{i \in R_k} \pi_i)^2}{D} \right) + \sum_{k=1}^n e_k \left( \sum_{j=1}^{|R_k|} \pi_{[j]} \sum_{i=j}^{|R_k|} t_{[i],[i+1]}^k \right) \right) \quad (5)$$

Additionally, we have to consider the feasibility condition for the cycle length by taking account of the fact that the delivery lot size of any vehicle should not exceed the vehicle's loading capacity. By definition, we know that the amount of items to be loaded on vehicle  $k$  is  $DT \sum_{i \in R_k} \pi_i$ , and that this quantity should not exceed the value of  $a_k$ , i.e.,  $T \leq \frac{a_k}{D \sum_{i \in R_k} \pi_i}$ . From the above statements, the optimal cycle length for this problem can be established as follows:

$$T^*(\pi, Z) = \min(\min\{T_k^{\max} | 1 \leq k \leq n\}, T^0(\pi, Z)), \text{ where } T_k^{\max} = \frac{a_k}{D \sum_{i \in R_k} \pi_i} \quad (6)$$

Finally, our problem can be summarised as seen below:

**Minimise**

$$f(\pi, Z) = \sqrt{2(A + \sum_{i=1}^m S_i + \sum_{k=1}^n c_k \tau_k) \left( \sum_{i=1}^m \frac{h_i \pi_i^2}{P_i} + h_b \sum_{k=1}^n \frac{(\sum_{i \in R_k} \pi_i)^2}{D} \right) + \sum_{k=1}^n \theta_k \left( \sum_{j=1}^{|R_k|} \pi_{[j]} \sum_{i=j}^{|R_k|} t_{[i],[i+1]}^k \right)} \quad (7)$$

**Subject to**

Lot-Sizing Constraints:

$$T = \min(\min\{T_k^{max} | 1 \leq k \leq n\}, T^0(\pi, Z)), \text{ where } T_k^{max} = \frac{a_k}{D \sum_{i \in R_k} \pi_i}, \forall k \quad (8)$$

$$\tau_k \leq T, \forall k \quad (9)$$

$$\frac{q_i}{P_i} \leq T, \forall i \quad (10)$$

$$\sum_{i=1}^m \pi_i = 1, \text{ where } \pi_i \in (0,1) \quad (11)$$

Routing Constraints:

$$\sum_{k=1}^n \sum_{j=1, j \neq i}^m x_{ji}^k = 1, \forall i \quad (12)$$

$$\sum_{k=1}^n \sum_{j=1, j \neq i}^m x_{ij}^k = 1, \forall i \quad (13)$$

$$\sum_{i=1}^m x_{is}^k = \sum_{j=1}^m x_{sj}^k, \forall k, s \quad (14)$$

$$\sum_{j=1}^m x_{0j}^k = 1, \forall k \quad (15)$$

$$\sum_{j=1}^m x_{j0}^k = 1, \forall k \quad (16)$$

$$U_j^k \geq q_j, \forall j, k \quad (17)$$

$$U_j^k \leq a_k, \forall j, k \quad (18)$$

$$U_j^k \geq U_i^k + q_j - a_k + a_k(x_{ji}^k + x_{ij}^k) - (q_j + q_i)x_{ij}^k, \forall k, j \text{ and } j \neq i \quad (19)$$

$$U_j^k \leq a_k - (a_k - q_j)x_{0j}^k, \forall j, k \quad (20)$$

$$U_j^k \geq q_j + \sum_{i=1}^m q_i x_{ij}^k, \forall j, k \quad (21)$$

The constraints (12) to (21) are used to ensure feasibility of the Vehicle Routing Problem (VRP) (see Kara et al., 2004). In the following, we assume in addition that the lot allocation policies for all suppliers are established according to the production capacities of the suppliers, i.e.,  $\pi_i = \left( \frac{P_i}{\sum_{j=1}^m P_j} \right), \forall i$ .

**NUMERICAL EXAMPLES**

In this section, we provide two examples to illustrate the behaviour of our model. For brevity of presentation, we consider a scenario where two heterogeneous vehicles are used to deliver items from a total of five suppliers to the buyer, i.e.,  $m = 5$  and  $n = 2$ . The data set for the suppliers used in this example is shown in Table 1.

Table 1 Suppliers' parameters

Supplier No.	Location		Production Capacity ( $P_i$ )	Set-up Cost ( $S_i$ )	Holding Cost ( $h_i$ )	Lot Allocation ( $\pi_i$ )
	X	Y				
1	58	50	607	126	4	0,21
2	22	94	526	106	3	0,18
3	16	41	515	103	3	0,18
4	70	36	634	133	5	0,22
5	65	92	622	130	4	0,21

In addition, we assume that  $A = 52, D = 1730, h_b = 6$  and the location of the buyer  $(X, Y) = (63, 84)$ . In addition, the capacity of vehicle 1 was assumed to be 429 and the speed of vehicle 1 83 km/h, whereas the capacity of vehicle 2 was assumed to be 424 and the speed of vehicle 2 75 km/h.

We compared the optimal lot-sizing and routing policies for two different objectives, namely I) the minimization of routing time (costs) and II) the minimization of the sum of greenhouse gas emissions (cost) and routing time (cost). Two cases were considered: I) low vehicle operating/emission cost and II) high vehicle operating/emission cost. A Mixed-Integer Non-Linear Problem was implemented using the LINGO Solver for numerical analyses. The results for both cases are illustrated in Tables 4 and 5 and Figures 3 and 4.

**Case 1)** Vehicle-1:  $(c_{1r}, e_{1r}) = (288, 363)$ , Vehicle-2:  $(c_{2r}, e_{2r}) = (287, 63)$

Table 4 Comparison of optimal policies for the two objectives for Case 1)

Decision Variables		Routing Cost Only	Routing Cost + Emission Cost
Cycle Length ( $T$ )		0.375	0.375
Buyer's Order Quantity ( $Q$ )		648	648
Suppliers' Production Lot ( $q_i$ )		(135,117,115,142,139)	(135,117,115,142,139)
Vehicle Routing ( $Z_R$ )	Vehicle-1	0 → S2 → S3 → S1 → 0	0 → S4 → S5 → 0
	Vehicle-2	0 → S5 → S4 → 0	0 → S2 → S3 → S1 → 0
Routing Distance ( $d_R$ )	Vehicle-1	173	113
	Vehicle-2	113	173
Delivery Quantity ( $B_R$ )	Vehicle-1	368	280
	Vehicle-2	280	368

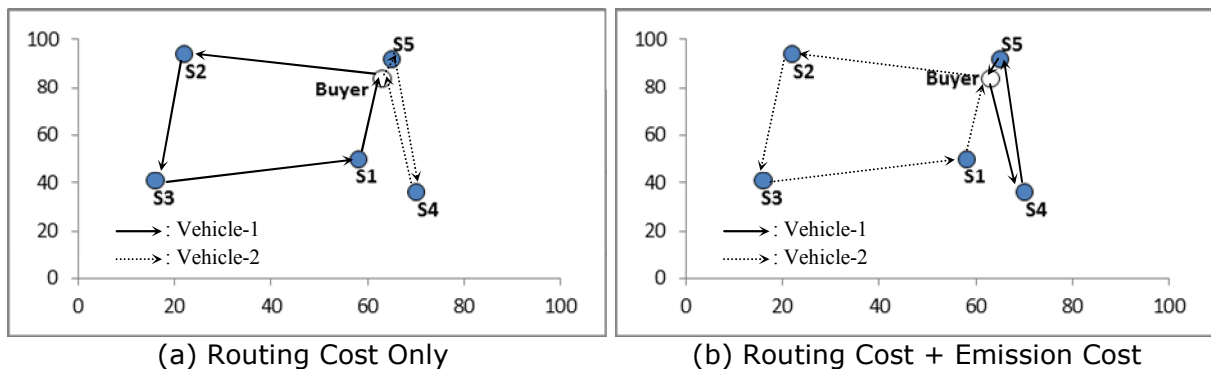


Figure 3. Illustration of lot-sizing and routing decision for Case 1)

As can be seen in Table 4, for Case 1, the question whether only routing cost or the sum of routing and emission costs are minimised does not influence the cycle time or the buyer's order quantity. The difference between both cases is that the assignment of vehicles to routes changes as emission cost are taken into account. If emission cost are considered, the vehicle with the lower emission cost factor,  $e_{1r}$ , is assigned to the longer tour to economise on emission cost. Figure 3 illustrates that the tours remain the same, but that the assignment of vehicles to tours changes.

**Case 2)** Vehicle-1:  $(c_{1r}, e_{1r}) = (705, 153)$ , Vehicle-2:  $(c_{2r}, e_{2r}) = (521, 174)$

Table 5 Comparison of optimal policies for the two objectives for Case 2)

Decision Variables		Routing Cost Only	Routing Cost + Emission Cost
Cycle Length ( $T$ )		0.372	0.373
Buyer's Order Quantity ( $Q$ )		644	646
Suppliers' Production Lot ( $q_i$ )		(135,117,114,141,138)	(135,117,115,141,138)
Vehicle Routing ( $Z_R$ )	Vehicle-1	0 → S5 → S2 → 0	0 → S5 → S4 → S1 → 0
	Vehicle-2	0 → S3 → S4 → S1 → 0	0 → S3 → S2 → 0
Routing		93.5	117



Distance( $d_{ij}$ )	Vehicle-2	171	159
Delivery Quantity( $B_{ij}$ )	Vehicle-1	254	414
	Vehicle-2	389	232

(a) Routing Cost Only (b) Routing Cost + Emission Cost  
Figure 4. Illustration of lot-sizing and routing decision for Case 2)

For Case 2, Table 5 illustrates that minimising the sum of routing and emission costs, instead of routing cost only, leads to a slightly longer cycle time and a larger order quantity of the buyer. In addition, the routes of the vehicles are restructured in such a way that the vehicle with the higher emission cost factor (vehicle 2) has to travel a shorter distance. Figure 4 illustrates the change in the tours.

### CONCLUSION

This paper studied a multiple-supplier-single-buyer supply chain that uses a heterogeneous vehicle fleet for transporting products. A mathematical model was developed and analysed in numerical studies. The results of the studies indicated that considering emission cost in the optimization problem may lead to different routing and production policies for the system. This has two major implications: First, if generating greenhouse gas emissions results in costs, these costs need to be considered in planning production and delivery activities in a supply chain to make sure that the system is efficiently coordinated. Secondly, assigning a cost value to greenhouse gas emissions generated in production and logistics is an appropriate measure to influence the behaviour of supply chains. Thus, introducing taxes on certain types of greenhouse gas emissions seems to be a useful mechanism to induce companies to reduce greenhouse gas emissions, provided that the emissions can be measured.

The model developed in this paper could be extended in various directions. First, this study assumed that the allocation of the buyer's purchasing quantity to the suppliers is determined based on the suppliers' individual production capacities. Thus, all available suppliers are used to meet the buyer's demand. In an extension of this paper, the design of the supply network could be considered in addition, and the issue of determining the optimal set of suppliers could be integrated (see, e.g., Glock, 2011). Secondly, this study assumed that the set of vehicles is given. Since the operational attributes of the vehicles in a fleet can differ from each other, the selection and allocation of vehicles to routes would be an additional important design variable in optimizing the overall supply chain efficiency. We leave these and other extensions for future research.

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# **INTER-FIRM NETWORKING: A CONCEPTUAL FRAMEWORK FOR COLD CHAIN COOPETITION AND REDUCTION OF PERISHABLE FOOD WASTAGE**

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## **ABSTRACT**

Owing to the unique operational characteristics, cold (supply) chain relies heavily on massive capital investment on technologies to maintain, trace, monitor and transport perishable goods to ensure product quality. However, almost one third of the food produced annually for human consumption is lost in the supply chain before or after it reaches the consumers. Fragmented operations, over-emphasis on self-interests, abuse of processes, and lack of visibility and transparency are some of the causes for the product deterioration. While competitions among business partners in a cold chain may be inevitable, collaboration allows competing firms to leverage the expertise and experiences of others on an operational basis to perform better together than they do separately. This paper presents a conceptual framework for cold chain collaboration proposing a healthy coopetition allowing competing firms to pool their respective resources and capabilities to meet the operational challenges in the cold chain to reduce food wastage. Such collaborative coopetition among firms in the cold chain will help minimize the huge capital infusion needed for the equipment, technologies, knowledge enhancement for overall operations improvement. The outcome will be reduction in food wastage and improvement in product quality due to reduced lead time and better visibility and traceability.

## **INTRODUCTION AND BACKGROUND**

The food system highly impacts on sustainability and the environment through consumption of energy and fresh water supplies, waste production or pollution from production and food transportation (Lundqvist 2008). It is estimated that 30-50% of the four billion tons of food produced annually is wasted and is never consumed (Gustavsson et al., 2011). The importance of food and its contribution in feeding the burgeoning population which is expected to reach 9.2 billion by 2050 has prompted numerous avenues to arrest food wastage. Wasting food is not just about hungry stomachs but losing life supporting nutrition and precious resources including land, water and energy. Infusion of new processes and technology which require heavy capital investments and standard practices are some means of improving efficiencies across the entire food supply chain. This has given rise to the need for closer relationships among players, even among competitors, in the chain to remove obstacles to increase efficiency.

## **COOPERATION AND COMPETITION LEAD TO COOPETITION**

Competition is the driving force in commercial activity. Business is viewed as a 'game' where winners reap the benefits and therefore all players are competitors. Competition is considered healthy as it drives down prices and provide scope for innovation. Efficiency and being effective are some of the alternative means that organisations are looking for to reinvent their business strategies to remain competitive. Being competitive professes the search for supernormal profits through gaining an advantageous position in the field of business (Porter, 1980) or by deploying available resources and/or offering exceptional and competent services that differentiates it from its immediate competitors (Prahalad and Hamel, 1990). Competitors close to each other observe each other's moves, enabling

them to imitate each other's products. Prestige and pride also stimulate companies to compete aggressively to innovate. Competition increases the dynamics between competitors. Successful companies are identified through their ability to create, invent and innovate (Osarenkhoe, 2010).

Globalisation, however, has reduced this victor-vanquished view of businesses and set the notion that survival depends on strategic alliances, joint ventures and team creation to maximise customer satisfaction, even to the extent of working with competitors to raise the long term value of the firm. Businesses can yield synergies when they cooperate. Telecommunication companies sharing costs to lay the optical fibre networks and competing television networks sharing same transmitting station can be cited as examples of such cooperation. Others include relationship between Dell and IBM, IBM and Microsoft and SAP with Oracle (Walley, 2007). Rather than being divisive, these firms have adopted an integrated approach known as coepetition where both cooperation and competition prevail. This inter firm networking thrives on collaboration. According to Blomqvist et al., (2005), cooperativeness and competitiveness in successful companies are determined by their proximity to the customers they are aiming to attract. Firms tend to compete when they close to the customers and cooperate in activities when they are far from the customers; the former focuses on value sharing strategies whereas the latter focuses on strategies for value generation (Vel et al., 2010).

To investigate how collaboration can turn costly competition to healthy coepetition that benefits all parties involved in the cold chain operations, this study used a desktop research methodology to identify the various drivers and barriers to cold chain coepetition as well as the key elements for cooperation. Case studies and industry reports on cold chain collaborative coepetition were reviewed to compare among different situations. Preliminary discussions with practitioners were also used to identify the critical elements of coepetition and success factors for implementation. The outcome of the analysis is a framework that encapsulates the attributes, issues, elements, outcome, and benefits of cold chain coepetition.

## **COLD CHAIN CHARACTERISTICS AND THE NEED FOR COOPETITION**

The primary role of food cold chain, just as any other supply chain, is to support the businesses and create a competitive advantage environment through collaborative efforts of all its players. However, due to its unique operational characteristics, cold (supply) chain relies heavily on massive capital investments on technologies to help maintain, trace, monitor and transport perishable goods to ensure product quality (Matopoulos et al., 2007). While the concepts of the ambient supply chain apply for the cold chain, the differences between them should be recognised. Some of the main differences include a) seasonality – for both supply and demand b) health, nutrition and safety – food has an impact on the health and wellbeing of consumers. Thus issues of quality, traceability, safety and risks must be managed c) short shelf life and unpredictable demand – food products have short shelf life and demand variations must be considered, supported by agility and d) impact on environment – food has inverse effect on environment as it uses natural resources such as water, land and energy extensively and emits carbon dioxide and leaves unintended waste.

In a vertical supply chain relationship flow, the firms deal with movement of goods from suppliers to consumers; they are visible and built on distribution of activities and resources. When these firms look beyond their borders to work horizontally with their peers (competitors) they are forced to interact with each other giving rise to mutual dependence between them (Wood, 2010). Horizontal relationships are between parties that are engaged in similar activities, competing with each other and that are at the same stage in the supply chain (Nassimbeni, 2004). Such relationships lead to

cooperative interactions. Coopetition is a state when members of similar industry compete and cooperate at the same time (Brandenburger and Nalebuff, 1996).

Competitors in the cold chain must overcome the barrier of inter firm rivalry to develop joint processes to encourage coordination of activities that are needed to meet the unique characteristics of the cold chain and the concepts of the goods that move within. Changing economic environment may lead to intersection of competitors pursuing similar goals, leading to coopetition in the cold chain. This is where firms seek to access to resources or capabilities that they do not possess without resorting to developing themselves, which can be an expensive, complicated or lengthy exercise (Wood, 2012). Temperature control to maintain freshness, effective transparency through traceability systems and the agile movement of perishables through the cold chain require heavy investments. The many players involved in the cold chain – from farmers to retailers too complicate movement along the chain with limited information and knowledge exchange possibilities. Added to these are fragmented ownerships and non-standardised practices. Managing such complexities may prove arduous for competing firms. Coopetition may prove useful for them and the perishable food movement in the cold chain.

In the cold chain, due to the heavy demands on capital investments, coopetition can help sustain investments in storage equipment, infrastructure, information systems, research and development, standardized processes and knowledge expansion. Partners in a cooperative cold chain can gain stronger competitive advantage by pooling inter-firm efficiencies and capabilities. As these needs are paramount at the onset of the cold chain activities which is far from final consumption, the end result will be satisfied customers who inevitably will drive up market shares and sales, thus maximizing profits and returns on investments. The cooperative setting is achieved by consistent information sharing, decision synchronization, conflict resolution and above all, through trust. This cooperation between competitors result in the development of a new product or service that create value and that goods or services are later competitively sold or distributed to get a share of the market and the value that it has created.

## **DRIVERS AND BARRIERS OF COLD CHAIN COOPETITION**

Food security is a situation when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs. Increases in the efficiency and productivity of food systems through coopetition, will result in success in reducing the prevalence of hunger and improving nutrition (Erickson, 2008; IFAD, 2012). Aligning different interests towards a common objective and helping to create opportunities for competitive advantage drive coopetition (Osarenkhoe, 2010). Successful coopetition is based on trust, commitment, voluntary and mutual agreement, documented or otherwise aimed at achieving common goals and value generation (Tanghe et al. 2010; Wang and Krakover, 2008). The entrance of global retailers, changing consumer attitudes in tastes and preferences, technological advances, political influences, institutional pressures and regulatory requirements and the increasing awareness of environment and sustainability among consumers are some of the changes facing the cold chain. On the other hand, market structure and power, non-standardised processes and procedures, fragmented ownership, lack of knowledge of the product and operations as well as lack of investments form barriers that disallow coopetition to thrive (Table 1).

<b>Drivers</b>	<b>Barriers</b>
. complexity due to globalisation	. market structure and power
. institutional pressures and regulatory requirements	. non-standardised processes and procedures
. consumer tastes and lifestyles	. fragmented ownership
. technological advancements	. lack of product knowledge
. environmental and sustainability	. lack of investments

Table 1: Drivers and barriers of cold chain coopetition

The global market for perishable food and prepared meals is growing due to the changing lifestyles and overall decreasing tariffs. Owing to their common fragility and limited lifetime, handling these goods in the cold chain is complex. Globalisation has instigated the understanding the global landscape and identifying real opportunities, balancing risks and rewards, maintaining flexibility and managing costs and complexities (Deardoff and Stern, 2002).

Politics remains an important change driver where businesses (including the cold chain) struggle to manage the impacts of the agreements and understandings reached between the trading nations. Competitors in the cold chain, in cooperative manner, discuss and make representations and proposals to the governments and regulatory bodies. By introducing mandatory regulations, governments not only ensure markets operate properly but also to give the lead in creating a positive environment for consumers and businesses. These regulations can be increasingly sensitive to other governments and businesses that need to adhere to them in the global arena.

The tumbling of trade barriers and tariffs has resulted in changes in the market structure and sometimes one party in a cooperative relationship wields power over others and this is detrimental to the relationship. Fragmented ownership makes pooling of resources difficult which leads to investment issues. This disrupts sharing of product knowledge and information and hampers the implementation of processes and procedures. These barriers stifle cooperation.

Continuous technological improvements in keeping, tracing, monitoring and transporting fresh foods are key elements that drive the cold chain (Fearne and Hughes 1999). They are expensive and complicated. Cooperation reduces burden on players.

## **A PROPOSED COLD CHAIN COOPERATION FRAMEWORK**

In the cold chain, fragmented ownership, inadequate capital investment, lack of processes and procedures, limited knowledge sharing and uncoordinated operations are some of the causes that lead to issues as depicted in Figure 1. These lead to issues such as temperature abuse, lack of traceability, reduced agility, lack of standardised practices, lack of aligned performance measurement and minimal information sharing. At the upstream of the cold chain where activities involving farmers, cooling/chilling/freezing stations and the transportation and storage mediums, the non-adherence of the food handling requirements will immediately trigger spoilage or wastage. Cooperation allows competing chain members to pool their unique competencies to create synergies that result in better outcome than when firms act individually. Such cooperative activities not only reduce food wastage in the cold chain but also provide long term benefits to the cooperative partners in generating greater efficiency, better effectiveness and more robustness thus tightening the cooperation/cooperative environment among the competitive players, ensuring that each reaps higher profitability.

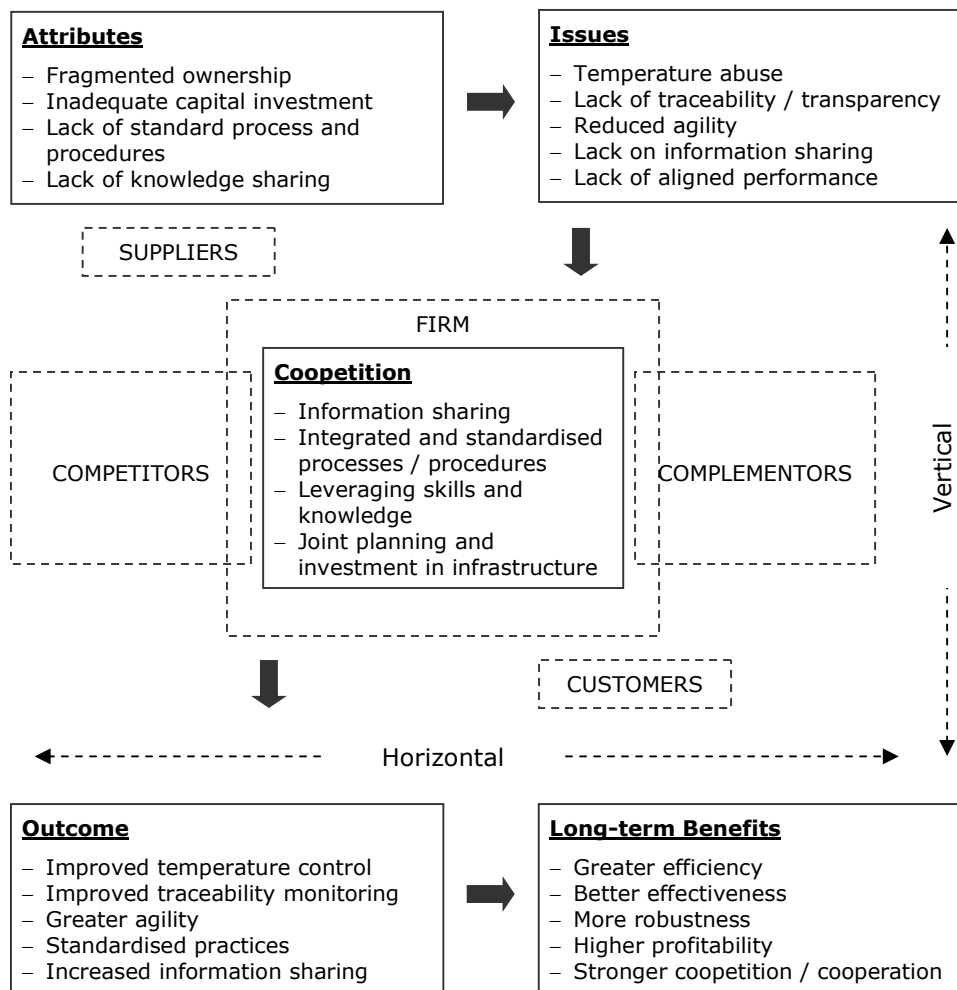


Figure 1: Conceptual framework for Coopetition in the Cold Chain

## IMPLEMENTATION FOR SUCCESSFUL COOPETITION

To be successful, a range of disciplines in the cold chain management must be strengthened and work well. Possible opportunistic behaviours by competitors in a coopetition environment should not happen. The distribution of power and control must be in place for an alliance to work. Mutual objectives, complementary needs, shared risks and rewards are similarly important (Lewis, 1992). The setting up of standards and processes in the cold chain (industry) will lead to collaborative coordination of the different activities between partners and will be a performance driver. Such standards will identify certain industry norms and behaviour that will enhance goods movement in the channel. Trust is important and strategic trust based alliances in coopetition will further strengthen activities among partners (Tanghe et al., 2010). Others include commitment, information and social exchange, defined goals and implementation phase and time, top management support and training and knowledge sharing (Bengtson and Kock, 2000). The processes that allow successful coopetition such as information sharing, leveraging skills and knowledge, joint planning and investment in infrastructure and the aligned performance measurements tackle the issues identified. These result in the long term benefits for the cold chain such as greater efficiency, effectiveness and robustness. They lead to higher profitability and even stronger coopetition and cooperation. Further examples of coopetition are the automobile industry between competing firms such as Renault and Volvo. Nokia, Sony Ericsson and Samsung have been in coopetitive cooperation in the mobile phone industry (Bengtsson et al., 2010). In the FMCG industry,

competitors such as Unilever, Colgate-Palmolive and Proctor and Gamble are in competition to drive down transportation costs by employing the services of stockists to deliver their products to the customers. Unilever, Proctor and Gamble and Henkel were fined in 2011 for involving in price fixing of detergent powders in Europe between 2002 and 2005 (The Guardian, 2011), which can be considered negative cooperation.

## **MANAGERIAL AND SOCIAL IMPLICATIONS**

Cooperation brings to table competitors in an industry who are willing to cooperate and collaborate to achieve operational synergies and to perform better together than they can individually. The proposed framework provides an overview of the attributes of the various issues with cold chain operations and a road map to fruitful cooperation. The key is on knowledge sharing, standardization of processes and procedures, and learning and pooling of resources. Cold chain managers can make use of the framework to formulate cooperation strategies and prioritize allocation of resources to achieve maximum efficiency and responsiveness across the entire cold chain.

Cold chain cooperation, if proves successful, can help reduce significantly the amount of food wastage in the supply process. This helps lessen the global food shortage problem and reduce water, land and energy consumption for growing more food and transporting it to the market. As such, successful cold chain cooperation can bring about considerable tangible economical as well as intangible social benefits.

## **CONCLUSION**

Food wasted along the food supply chain (and cold chain) is the outcome of several factors – the market economy, resource limitations (seeds, fertilisers, insecticides) and climate, legislation and cultural differences. While lack of infrastructure, technical and managerial skills in food production and postharvest processing have been identified as the main causes for food losses in developing countries, developed nations attribute food losses to post consumer purchases, driven by the low prices of food against disposable income, high expectations of food visual impact and the continuing disconnection between the consumers and how food is produced (WFP, 2009). Resource and commodity limitations due to growing populations and impact of climate changes are forcing more efficient processes to be in place to reduce waste. Cooperative agile food chains with controls and monitoring, better demand forecasting, sophisticated kitchen utensils, 'informed' consumers, large scale investment in agricultural infrastructure, technological skills and knowledge, good storage, transport and distribution facilities are needed. In developing countries, the governments should lead from the front through locally supported policies. Such changes and awareness are needed worldwide to arrest wastage in both developed and developing economies (WFP, 2009).

In today's competitive world, the food industry must work as a whole entity. With increasing global consolidation through supply chain, individual sectors will not have the capacity to compete separately. Competitiveness will depend on the efficiency and value of services and infrastructure provided within the whole chain. It is important for each sector to understand how value is created within the chain through transformation of products or services provided to deliver to the consumers. The food contributes significantly to the nutrition, health and well-being of the consumers. Key drivers in consumer food purchasing patterns are shopping convenience, product availability, price and value for money, food taste and enjoyment, food safety and nutritional value (Horticulture Australia Limited, 2011). The global market is built on innovation through communication, transport and technology (AVIDG, 2006). It is becoming increasingly evident that the demands of consumers cannot be met solely by the efforts of a single company. As each company is just one link in the cold chain, they must cooperate and



collaborate. The more effectively this is done, the stronger the chain will be and higher its competitive position in the markets. It is hoped that the conceptual framework for cold chain cooperation proposed in this study could serve as a basis for practitioners in the industry to review and improve current operations. Continuous research in cold chain cooperation and collaboration would also assist the industry in moving towards running cold chains in a cost efficient manner with minimum wastage.

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**(Further references will be provided on request)**

# GREEN SUPPLY CHAIN MANAGEMENT AS IDEA, THEORY OR POTENTIAL OF COMPETITIVENESS – ANALYSIS OF LITERATURE

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## 1. Introduction

The purpose of the green supply chain (GSCM) offers a new perspective and a way to innovate the supply chain. Green thinking, as part of the strategy is now a global trend. The Knowing of GSC include in the environmental context of supply chain, therefore managers of supply chain search for possibilities of implementing innovation and more competitiveness for the global market. Theoretical and practical aspects about GSC are talked since 1990`s, wherein this work is attempted to represent an overview of the theoretical changes of the GSC especially by existing literature (books, reports and journals). The aim is proved if the definitions are changing, and how many empirical and theoretical studies are present. Knowing the wider perspective of the GSC is important to create of the competitiveness advantage, which of instruments should be used to make of competitiveness in global Word.

The present study shall indicate, whether the last few years' interest in the subject has changed and if there are new definitions of the alleged problems, what a reference is to the practice of business. Many literature studies and overviews [Beamon 1999, Srivastava 2007, Fortes 2009, McKinnon, 2010] about GSC is intended to help clarify this theme. However, the purpose of this study is to identify differences in the meaning of green supply chain. The conclusion of the paper is a statement and understanding of implementation about green chain.

## 2. Green supply chain – available, theoretical information – explain of an example of the selected literature review

A better understanding of facts and scope of the green supply chain should contribute to the achievement of competitive advantage. A thorough analysis of selected literature shows interest in the subject of nearly 25 years. The theoretical point of view shows, that in understanding of the definition of GSC, there are occur no revolutionary alteration.

The key drivers remain the same, there is just a deepening and expanding of the area of application. Analysis of research, including references to business practice in this area, proves, that authors are based on over dozen of world-class publications which are form the theoretical basis of green supply chain. The selected areas and the authors are presented in table 1.

Table 1. Areas of supply chain – analysis of selected authors and description of evaluation

area	Author	Description
Green operations	Kelle, Silver's (1989), Pohlen, Farris (1992); Stock (1998), Tibben, Limbke (2002)	case studies on reverse logistics
Green design	Navin-Chandra's (1991)	green design is used to reduce the impact of product waste
	Ashley (1993); Allenby, Richards (1994), Zhang, Kuo, Lu, Huang (1997)	framework of green design
	Arena, Mastellone and Perugini (2003), Beamon (1999), De Ron Penev (1995)	Life-cycle analysis was an example of a framework that came out of green design

Reverse logistics	Carter, Ellram, (1998); Srivastava, Srivastava, (2005); Shih, (2001); Nagorney, Toyasaki, (2005), Min, Ko, Ko, (2006)	Academic perspectives
Waste management	Roy, Whelan (1992).	created a standardised model for reducing electronic waste without harming the environment
	Owen (1930), Hannah, Newman (1995); Sarkis, Cordeiro (2001), Nagorney, Toyasaki (2005)	trends of waste management becoming an issue.
Green manufacturing	Crainic, Gendreau, Dejax (1993).	a comprehensive GSC model in terms of transporting containers from land to sea and vice-versa.
	Van Der Laan, Salomon (1997); Guide, Srivastava (1998), White, Masanet, Rosen, Beckman (2003).	Ideas of Green manufacturing were then developed further
<b>Green supply chain contain</b>		
green production and planning and manufacturing		Bras & McIntosh, 1999; Sarkis & Cordeiro, 2001; Van der Laan, Salomon & Dekker, 1996
product recovery		Gungor & Gupta, 1999; Van Der Laan et al., 1996
recycling in the supply chain		Barros, Dekker, and Scholten (1998)
discussed product remanufacturing and disposal		Van Der Laan et al. (1996)
environmental technologies and design		Zhang et al. (1997)
Eco-efficiency, remanufacturing processes		Ashley, 1993; Srivastava, 2007
Global market demands and governmental pressures		Guide & Srivastava, 1998; Gungor & Gupta, 1999
<b>"Green" supply chain management is</b>		
an increasingly important issue for business		Sarkis, Zhu, & Lai, 2011; Vachon & Klassen, 2008, Capgemini Consulting's 2011
expected by employees		Carter & Jennings, 2004; Salam, 2009
expected by governments		Lee, 2008; Walker et al., 2008
<b>expected by companies to become benefits:</b>		
cost reduction		Carter & Dresner, 2001; Zhu & Sarkis, 2006
improved product		Lamming & Hampson, 1996
process quality		Lamming & Hampson, 1996
risk reduction		Welford & Frost, 2006
improved financial performance		Rao & Holt, 2005
power advantage of the buyer		Carter & Carter, 1998; Hall, 2000
create a multiplier effect		Preuss, 2001
<b>GSCM drivers</b>		
identified the factors that drive or hinder organizations to implement green supply chain management initiatives; these includes internal drivers as organizational factors, and external drivers as regulation, customers, competitors, society and suppliers		Walker (2008)
observed that greening different phases of the supply chain leads to an integrated green supply chain, which in turn leads to competitiveness and better economical and operational performance.		Rao and Holt (2005)
identified the main drivers for companies to participate in GSCM practices as buyer influence, government involvement and green supply chain (GSC) readiness.		Lee (2008)

identified seven critical factors in their research into environmental management: top management commitment; total involvement of employees; training; green products/process design; supplier management; measurement; information management.	Quazi (2005)
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Source: own elaboration based on: Diabat A., Govindan K., (2011), An analysis of the drivers affecting the implementation of green supply chain management, Resources, Conservation and Recycling;

### 3. Conceptual studies of Green supply chain – changing of definition

Most of conceptual and theoretical studies are focus of five areas: green design, green operations, reverse logistics, waste management and green manufacturing [Guide & Srivastava, 1998; Srivastava, 2007], they are sub-topics of creating of the green supply chain management. The presented table shows the discussion of the concepts and definitions of GSCM on the theoretical perspective, which is starting from the most frequently cited and widespread definition of GSC. Different researchers offer different definitions, the following table summarizes some of the definitions of GSC that have appeared in the literature

Table 2. Selected definition of green supply chain – analysis of literature

Author	Year	Definition
Srivastava	2007	The GSCM is integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life.
Zhu et al.,	2005	GSCM has emerged “as an important new archetype for enterprises to achieve profit and market share objectives by lowering their environmental risks and impacts while raising their ecological efficiency”
Gilbert	2001	greening the supply chain is the process of incorporating environmental criteria or concerns into organizational purchasing decisions and long-term relationships with suppliers. Indeed, there are three approaches to GSC: environment, strategy, and logistics.
Hwa, Nunes	2001 2004	Furthermore, the concept of Green productivity (GP) shows, that any development strategy to be sustainable, therefore it needs to have a focus on environment, quality, and profitability, which form the triple focus of GP.
Zsidisin, Siferd	2001	environmental supply chain management consists of a series of policies and actions on such issues as design, procurement, production, utilization, reutilization, and disposal, undertaken by businesses out of concern for the natural environment
Davies, Hochman	2007	GSCM is a concerted effort throughout the company and it is more than simply putting some green practices in place, but rather a consistent, holistic improvement of the environmental performance of all levels of management and on the shop-floor
Rettab, Brik	2008	the green supply chain is a managerial approach that seeks to minimize a product or service’s environmental and social impacts or ecological footprint.
Zhu, Sarkis	2004	The definition and scope of GSCM in the literature has ranged from green purchasing to integrated green supply chains flowing from supplier to manufacturer to customer, and even RL
Rao, Holt,	2005	advocating efficiency and synergy between partners, facilitates environmental performance, minimal waste and cost savings
Skjoett-Larsen	2000	“green” should include each link in the chain from initial manufacturer at the raw material stage to the end-user, including

		production, processing, packaging, shipping, handling activities
Vachon, Klassen	2008	asserts that environmental collaboration was defined specifically to focus on inter-organizational interactions between supply chain members including aspects such as joint environmental goal-setting, shared environmental planning, and working together to reduce pollution or other environment as impacts tried to minimize the unexpected environmental impacts of supply chain processes within the participating organizations and the whole supply chain

Green supply chain can bring many benefits. The most frequent positive effects include: improve efficiency, quality improvement, customer satisfaction, reduction of cost, risk reduction, reduced resource consumption and reducing CO2 emissions in logistics processes. For a growing number of managers are environmental aspects and the green chain is increasingly important [Cappgemini Consulting's 2011]. Interestingly it is not talked directly about the benefits in the form of competitive advantage. Although it is explained which points are important to give positive effects, benefits, in economical and social areas as well as individual cells and the entire chain, the aspects of competitive advantage for specific opportunities will not be in research achieve. Speaking about the superiority of the elements of GSC should be considered: identify costs, determine opportunities, calculate benefits, and decide, implement and monitor [EPA2000]. Some studies suggest an advantage for buyers [Carter & Carter, 1998; Hall, 2000], but the analysis of the literature shows that the focus is on the implementation of ideas of what green supply chain is. Nevertheless the idea of green supply chain is almost exhaustively described in the literature. Present, the trend is to implement the scientific principles of definition on the ground of economic practice, therefore researcher are using to define areas which are made, to verify the theoretical theses. That proves first of all the number of citations of the most important publications in the field, as well as specific items arising from them. As a Conclusion each of the presented publications are relating to the topic of green supply chain, theoretical foundations belong to the most important publications in the field: Beamon, Srivastava, Zhu, Sarkis, Hoek. This fact testifies to the significance of these assumptions, and of not having to create more definition.

#### 4. Assessment of changes in theoretical approach to carry out literature research

In literature there are more publications on issues of green supply chain. However, review of the literature shows clearly that in reviewing the literature and terminology aspect are basic definitions. The Review of literature shows that the initial focus on core activities and processes underwent evaluation. Currently, green supply chain means it is not only seen as green design, product sourcing, production, etc., Implements a green thought in every cell and every process, setting the basis for strategic thinking. The theoretical aspect is often used as a GSC strategy of the whole chain. Even in the few publications it appears as a source of visible and measurable competitive advantage. Evaluating the available literature review indicate the apparent interest in the subject, largely in the context of practical solutions and implementations.

#### 5. Conclusions

In the literature, the determinants of GSCM included: "external factors", mostly linked to stakeholders' pressure; and "internal factors", i.e., a specific business-led strategic process. GSC literatures has showed that GSCM is on focus not only on products and production processes but also includes materials sourcing on the immediate outcome of the supplier on green efforts. The meaning by which more green operations or products might be achieved as well as buyer requirements are often incorporated in the conceptualization of green supply chain. Partners can happen simultaneously upstream with the green suppliers [Zhu, Q., Sarkis, J., 2004, Bowen, F.E., et.al 2001].

The implementation of GSC can be an integral part of the contemporary market and done by market requirements. The results include cost reduction, resource conservation, public image improvement, and market competitiveness among others benefits. Variations in

the definition of green supply chain are only apply to specific areas or refer to a specific industry or sector. Theoretical foundations serve researchers to carry theoretical definition of the land business practice. The changes, which can be seen on the areas and seek opportunities to achieve even greater benefits when implementation of GSC, including competitive advantage.

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# GREEN SUPPLY CHAIN MODEL FOR THE THAI RUBBER INDUSTRY

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## ABSTRACT

The global supply chains continue to be more complex in term of environmentally concerns, therefore the needs to design supply chains to achieve environmentally friendly have emerged as new challenges for the Thai rubber industry. This paper aims to develop an optimization-based model for the Thai rubber industry in the manner to minimize total greenhouse gas (GHG) emissions. The model is formulated by incorporating production, distribution and transportation of rubber products. The minimization of total greenhouse gas (GHG) emissions from the Thai rubber supply chain is examined by using linear programming model. The results obtained show the flows associated with the capacity utilization percentage of rubber products between the supply chain members. Preliminary results based on greenhouse gas emissions minimization are presented and discussed.

**Keyword:** Green supply chain, Optimization-based model, Thai rubber industry

## INTRODUCTION

The increasing in environmental concerns from consumer and regulation requirement has pushed the company to redesign its supply chain to be more environmentally friendly. The society of automobile industry has stressed that environmental issues beat cost saving to be the industry's highest concerns in the first 14 years (Korzeniewski 2008). This is an important message to the automobile industry supply chain including the Thai rubber industry. This pressure will drive the industry to find the way to embrace this concern. The focus on environmental concerns will continue to pressure business to adopt green practice (Stead and Stead 2000; Mayorga E. and Subramanian 2009). In addition, the Thai Rubber Association has also highlighted the importance of the Thai rubber industry to produce environmentally friendly products (The Thai rubber Association 2008). Therefore the needs to design supply chains to achieve environmentally friendly have emerged as new challenges for the Thai rubber supply chain research paradigm. In this regard, the investigation into network design of the rubber industry supply chain incorporating the environmental criteria is seen as essential to support the Thai rubber industry policy maker decision making to enhance the industry's competitiveness. However, none of the prior research of the Thai rubber supply chain has dealt with the environmental issues. Thus, this paper seeks to fill this gap.

The objective of this paper is to present an optimization-based model for the Thai rubber supply chain formulated by incorporating the production, distribution, and transportation of rubber products in a manner to minimize total greenhouse gas (GHG) emissions. The purpose of the model is to support the analysis of rubber supply network flows, the factory locations, and the outbound distribution of transportation mode and route selection.

The remainder of this paper is organized as follows. First, the category of rubber product, the Thai rubber supply chain research, and greenhouse gas (GHG) emissions from the Thai rubber supply chain are presented. Next, model framework and mathematical model



for the Thai rubber supply chain are discussed. The paper is concluded with preliminary results, discussion and conclusion

### THE CATEGORY OF RUBBER PRODUCTS

Rubber can be harvested in a variety of forms, ranging from fresh latex, to the processed forms of block and sheet products. Fresh latex is extracted from rubber trees as a liquid. The fresh latex can be processed to primary rubber products such as field latex, un-smoked sheet or cup lump. These products are subsequently process to different intermediate rubber products. The intermediate rubber products are including concentrated latex, block rubber and ripped-smoked sheet rubber. The category of rubber products is depicted in Figure 1

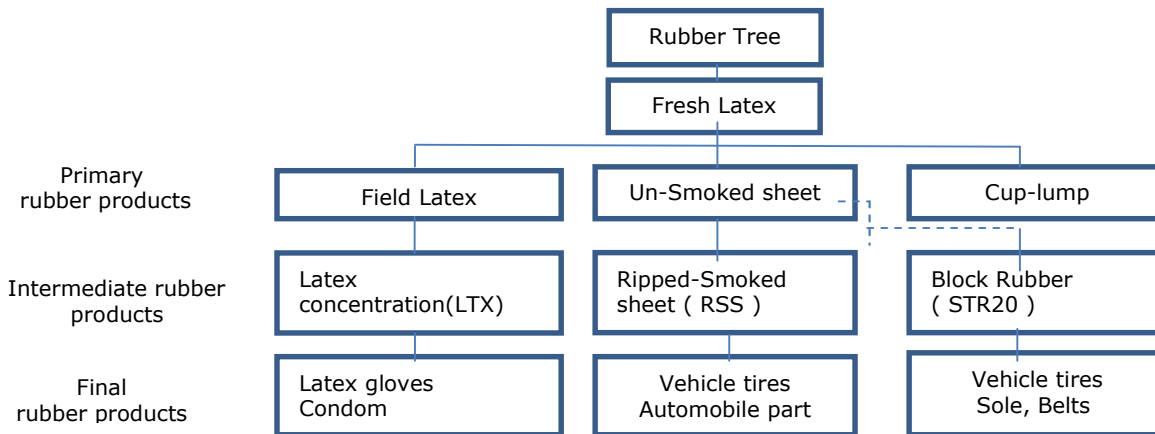


Figure 1: The category of rubber products

### THE THAI RUBBER SUPPLY CHAIN RESEARCH

The rubber supply chain research in Thailand began in 2008 due to the Asian-China Free Trade Agreement of rubber products (Wasusri and Chaichompoo 2008). The supply chain of the rubber industry was investigated in order to support Thailand strategic plan and policy to enhance the industry’s competitiveness over the FTA regulations. Wasusri and Chaichompoo (2008) studied the current outbound logistic networks of rubber industry export to China. Their research has provided the basis of the Thai rubber supply chain network flow. In addition, they also addressed the weakness of the chain, which is high transportation costs. Another research to investigate supply chain network in the Thai rubber industry is Kritchanhai (2009), who focus to examine the inbound supply chain network flow. The author found that unstructured supply chain network has emerged to obstruct the efficiency of the Thai rubber industry. In addition to Wasusri and Chaichompoo (2008) and Kritchanhai (2009), Kritchanhai Somboonvivat and Chanklai (2010) studied the supply chain of passenger car tire. The research findings have supported the earlier works that the inadequate transport infrastructure and unstructured supply chain have constrained the Thai rubber industry competitiveness.

This initial stage of the rubber supply chain research revealed the state of the Thai rubber supply chain and contributed to identifying and describing the weaknesses of the chain. However, none of the early works has dealt with the environmental issues from the Thai rubber supply chain. There are sufficient works (Wasusri and Chaichompoo 2008; Kritchanhai 2009, Kritchanhai Somboonvivat and Chanklai 2010) exist to explore the weaknesses of the Thai rubber supply chain. Nevertheless, there is a lack of appropriate models as a tool to manage the supply chain network flow especially in relation to the environmental issues.

### GREENHOUSE GAS (GHG) EMISSIONS FROM THE THAI RUBBER SUPPLY CHAIN

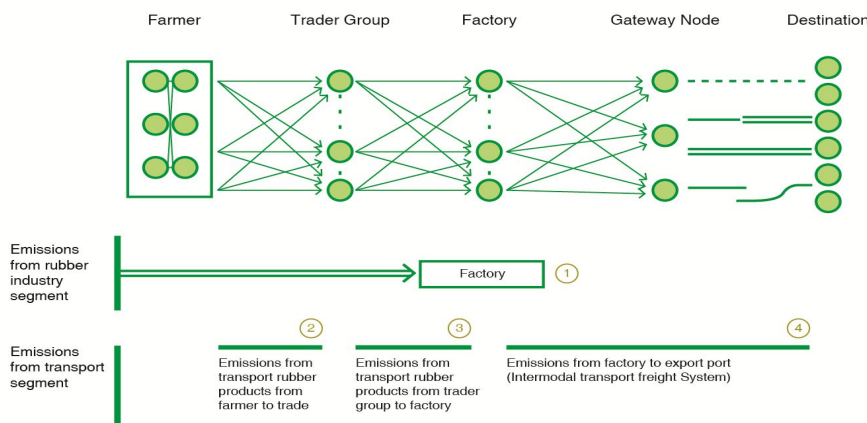
GHG emissions from the rubber industry segment arise from various stages, ranging from rubber plantation to the dispatching of intermediate rubber finished products. The

rubber plantation stage composes of three processes: rubber nursery, rubber plantation and primary rubber production. At this stage, rubber processes have emitted carbon dioxide (CO<sub>2</sub>) and Nitrous dioxide (N<sub>2</sub>O) due to land conversion and raw material used in rubber plantation and primary rubber production. At the intermediate rubber production stage, electricity and fuel used are major source of GHGs (Jawjit et al. 2010).

For transportation segment along the rubber supply chain, level and type of GHG emissions depend on mode of transportation, payload, and travelled distances. Since storage has not plays an important role in the Thai rubber industry, this paper will not take this stage's GHG emissions in to account. GHG emissions calculation for transportation in each route is calculated by an activity-based approach because rubber products have a relatively high density and operated by third party freight forwarder company. The activity based method formulation is shown as below:

$$\text{GHG emissions (Ton)} = \text{Weight of goods (Ton)} * \text{Total distance travelled (Km)} * \text{GHG conversion factor (Ton CO}_2 \text{ eq./Ton-Km)} \text{ (DEFRA 2012)}$$

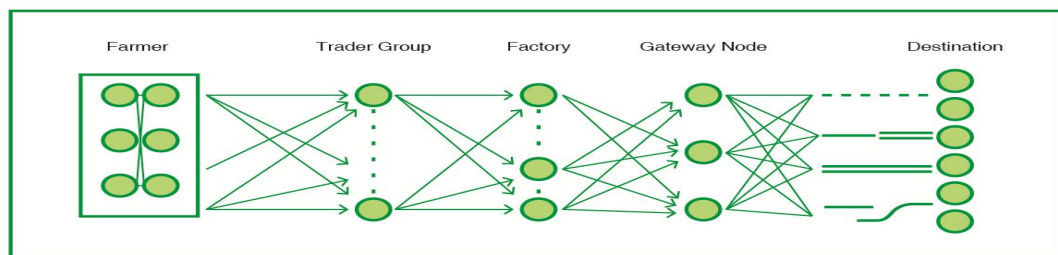
Therefore, total GHG emissions across the Thai rubber industry supply chain consist of both segments: rubber industry segment (1) (GHG emissions from rubber plantation and intermediate rubber production) and transportation segment (2+3+4) (GHG emissions from transportation along the supply chain). The Thai rubber industry supply chain GHG emissions calculation framework is illustrated in Figure 2. The rubber product GHG emissions and GHG conversion factors for each transportation mode is presented in Table 2 and Table 3 in APPENDIX.



**Figure 2 : The Thai rubber industry supply chain GHG emissions calculation framework**

### PROBLEM FORMULATION

This research defines the Thai rubber supply chain as a mathematical modelling using the optimization-based model approach. The main focus is formulating the mathematical programming that attempt to minimize the Thai rubber industry supply chain's total GHG emissions. The problem is based upon a model framework as depicted in Figure 3



**Figure 3: The Thai rubber supply chain model framework**

The Thai rubber supply chain is divided into fourteen provinces in southern Thailand. It is represented 79% of the total Thai rubber production. Regarding to rubber farmer group, it has been classified by the rubber plantation areas each rubber farmer occupy. There are three sizes of the Thai rubber farmer; small, medium, and large. Three types of primary rubber products have been examined in this model: un-smoked sheet (US), cup lump (CL) and field latex (LX). These products are raw material to produce intermediate rubber products: ripped-smoke sheet (RSS), block rubber (STR), and latex concentration (LCT) respectively. There are three trader groups in Thailand named general market (GM), cooperative (CO) and dealer (DL).

The inbound supply deals with primary rubber products produce from each farmer size before sold through each local market trader in each province. The market traders then subsequently deliver primary rubber products down the chain to factory to process intermediate rubber products in each factory in each province. Outbound distribution flow contains activities related to the transportation of intermediate rubber products from factory through gateway node to destinations. The outbound distribution flow is defined as intermodal freight transport network. It comprises of different freight modes combination such as road-rail-sea. Gateway node in this model represented the main rubber activities province in the region in terms of rubber trading, manufacturing and distribution. It also has intermodal terminals that handle regional rubber product shipments for domestic consumption and export. These intermodal terminal hubs for rail and inland waterway are serving the shipments to major ports in Thailand and Malaysia. Three gateway nodes are Songkhla, Suratthani and Nakhon Si Thammarat province. In addition, there are fourteen possible routes in these transport system networks as shown in Table 2 at APPENDIX.

The Thai rubber supply chain is presented as a mathematical formulation with single objective functions. The linear programming model has been chosen as a methodology to investigate this problem to find the flows associated with quantity of rubber products between supply chain entities (farmer, trader group, and factory) and the transportation mode and route in order to minimize the total GHG emissions. Objective (1) is to minimize the total GHG emissions of farmer processing primary rubber products, the trading group's GHG emissions, factory's processing intermediate rubber GHG emissions, freight route GHG emissions and the transportation GHG emissions from farmer to trading group, from trading group to factory, from factory to distribution node, from distribution node to freight route, and from freight route to destinations. Constraint (2) is the capacity constraint for farmer rubber production. Constraint (3) is trader group capacity constraint. Constraint (4) is factory production capacity constraint. Constraint (5) is distribution node capacity constraint. Constraint (6) is freight system capacity constraint. Constraint (7) is demand. Constraints (8), (9), and (10) define the percentage of primary rubber type to produce intermediate rubber products. The proportion of 20% of US and 80% of CL are raw material to produce STR. US is the only raw material to produce RSS while LCT use only LX for production. Constraints (11) and (12) are conservation flows. The model notation and decision variables are presented in Table 1 at APPENDIX.

## MATHEMATICAL MODEL

### Objective function:

$$\text{Min } Z_1 = \sum_i \sum_s \sum_p \sum_t \sum_g X_{ispitg} (ER_{sp} + ET_{stg} + EG_{gp}) + \sum_i \sum_g \sum_f \sum_e \sum_a Y_{igfea} (ET_{igf} + EF_{fe} + ET_{fa}) + \sum_e \sum_a \sum_b \sum_d Z_{eabd} (ET_{ab} + EM_b + ET_{bd}) \quad (1)$$

### Constraints:

$$\sum_p \sum_t \sum_g X_{ispitg} \leq SC_{si} \quad , \forall s \in S, \forall i \in I \quad (2)$$

$$\sum_s \sum_t X_{ispitg} \leq TGC_{gpi} \quad , \forall g \in G, \forall p \in P, \forall i \in I \quad (3)$$

$$\sum_i \sum_g \sum_a Y_{igfea} \leq FC_{fe} \quad , \forall f \in F, \forall e \in E \quad (4)$$

$$\sum_i \sum_g \sum_f \sum_e Y_{igfea} \leq DNC_a, \forall a \in A \quad (5)$$

$$\sum_g \sum_a \sum_d Z_{gabd} \leq FRG_b, \forall b \in B \quad (6)$$

$$\sum_a \sum_b Z_{gabd} \leq DE_{de}, \forall d \in D, \forall e \in E \quad (7)$$

$$0.2 * (\sum_i \sum_g \sum_f \sum_a Y_{igfSTR'a}) + (\sum_i \sum_g \sum_f \sum_a Y_{igfR3S'a}) = \sum_i \sum_g \sum_r \sum_g X_{ig'US'tg}, \forall e \in E, \forall p \in P \quad (8)$$

$$0.8 * (\sum_i \sum_g \sum_f \sum_a Y_{igfSTR'a}) = \sum_i \sum_g \sum_r \sum_g X_{ig'CL'tg}, \forall e \in E, \forall p \in P \quad (9)$$

$$(\sum_i \sum_g \sum_f \sum_a Y_{igfLCT'a}) = \sum_i \sum_g \sum_r \sum_g X_{ig'LK'tg} \quad (10)$$

$$\sum_i \sum_g \sum_p \sum_r X_{igp'tg} = \sum_i \sum_f \sum_e \sum_a Y_{igfea}, \forall g \in G \quad (11)$$

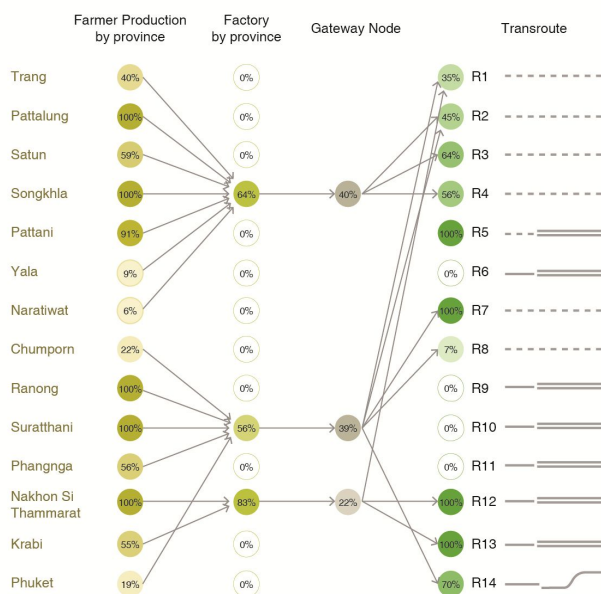
$$\sum_i \sum_g \sum_f Y_{igfea} = \sum_b \sum_d Z_{gabd}, \forall e \in E, \forall a \in A \quad (12)$$

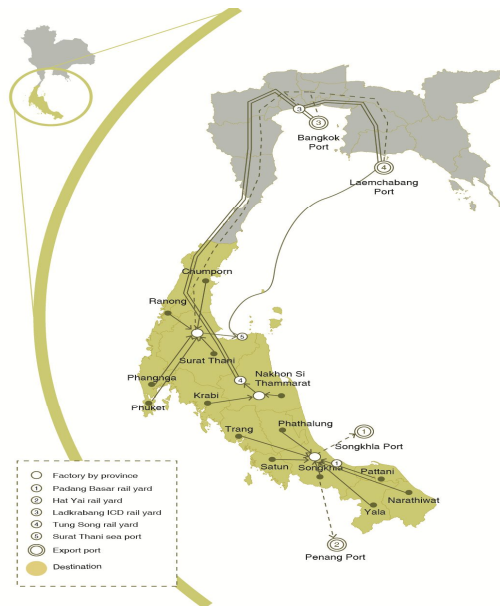
## PRELIMINARY RESULTS

The results of solving objective function (objective1) show that the optimal solution is to supply rubber products 176,259 Ton per month, which is giving a total GHG emissions of 191,478.5 Ton. This can be translated to 1.08 Ton GHG emissions per Ton product. According to the literature, this paper appeared to be the first attempt to calculated total GHG emissions of the Thai rubber supply chain. Therefore, we cannot find any reference for results comparison. The respective problem scope is specified by 6805 variables subjected to 299 constraints. The ILOG CPLEX version 12.4 (provided by IBM academic initiatives) used for formulating and solving the problem.

The model results has illustrated as the network flow as depicted in Figure 4. It shows the flow associated with the capacity utilization percentage of rubber products. The flow moves from farmer through trader group to factory to gateway node then subsequently to destination by each transportation freight route. In the network flow presentation, farmer production node, factory node, gateway node and trans-route node used to describe the rubber supply network flow in the system. It is noted that trader group node has not presented in the network flow. This is because the rubber trading activities are process at the provincial level rather than regional level. Each node at the farmer production and factory represented the summation of each province's capacity (14 provinces in Southern Thailand were defined), for instances, the factory capacity at Songkhla refers to summation of total factory capacity in Songkhla province. The gateway nodes refer to Songkhla, Suratthani and Nakhon Si Thammarat province. There are 14 nodes for transportation route represented route R1 to R14. The color and figure shown at the node signify capacity utilization percentage of each node. The darker shade mean higher percentage while greyer and whiter mean a lower percentage of capacity utilization allocated by the model.

**Figure 4: Network flow of solving objective function to minimize GHG emission from the Thai rubber supply chain**





**Figure 5: Transportation mode and route of GHGs minimisation in the study area**

According to the results as shown in Figure 4, several implications are provided as below:

1. Farmer production utilization allocated by the model: The model has allocated to produce 100% of farmer production capacity in each province to Pattalung, Songkhla, Ranong, Suratthani and Nakhon Si Thammarat province. It follows by 91% to Pattani, 59% to Satun, 56% to Phangnga, 55% to Krabi and 46% to Trang province. For other provinces, it was allocated between the ranges of 22% to 6% of total capacity in each province. Narathiwat province has the lowest percentage at 6%. For the primary rubber production allocation, the proportion of three primary rubber products US, CL and LX is 39%, 31% and 30% respectively. It can be seen that the gateway and surrounding provinces have the higher allocation percentage comparing to other provinces. The nearer to gateway province has the higher percentage. Regarding to farmer size's rubber production, the model has allocated farmer size S to produce 95% of total optimization supply volume, followed by farmer size M and L at 4% and 1% respectively. This is concordance with the current industrial practice that farmer size S is the dominated group of rubber farmer in Thailand.
2. Factory capacity utilization allocated by the model: The model has allocated the production to factory at Songkhla 64%, factory at Suratthani 56% and factory at Nakhon Si Thammarat 83% of each province's total production capacity. Regarding to the intermediate rubber products, the allocation is allocated to STR production 39%, follow by RSS 31% and LCT 30
3. Transportation freight route capacity utilization: Route R5, R7, R12, R13 was allocated to used 100% of the total capacity. These routes are road-rail intermodal transport. Route 14, the road-inland waterway transport is the second largest percentage allocation at 70%. For direct road transport, R3 to Songkhla port, R4 to Penang port, R2 to domestic consumption, R1 to country stock and R8 to Bangkok port's allocation is 64%, 56%, 45%, 35% and 7%. The model has not assigned any shipment to route R6, R9, R10 and R11. From the results, it can be seen that the model has prioritized to allocate the volume to the road-rail intermodal transportation, which is the lowest GHG emissions transportation system then to road-inland waterway transportation system. The direct road transport is allocated to the short distance travelled such as route R3 and R4 from Songkhla province and for the domestic shipment to country stock and domestic consumption as truck is the only mode available for domestic customers. It is also noticed that R6, R10 and R11 has no capacity allocation even though these are the road-rail intermodal transportation system. This is because of the bottleneck rail service capacity from Hatyai to Padang Basar and Hatyai to Ladkrabang ICD. This short-haul bottleneck capacity is limited the long-haul route capacity. If these

routes are operated with a proper capacity, it will impact to reduce the total GHG emissions of the whole supply chain.

## DISCUSSION

Overall the proposed model has provided decision support tool for the Thai rubber policy maker to select the optimum rubber supply networks with regard to minimize the total GHG emissions. The Thai rubber policy maker could take an action to look to the entire rubber supply chain to lay down the strategies to drive the industry achieve the green objective. The strategies from this research implication may include rubber plantation zoning, rubber trading mechanism, and rubber production volume quota. Another important strategy is to facilitate the expansion of low emissions transportation mode such as rail and in land waterway.

However, green supply chain management is not only concern about environmental criteria but also economic criteria. When incorporating environmental criteria into supply chain management, the decision maker has been forcing to address the trade-offs between environmental impact and economic performance.

Therefore, the future research will be open to formulating a model to incorporated cost and GHG emissions as a multi objective optimization problem for the Thai rubber supply chain.

## CONCLUSION

In this paper, an optimization-based decision support model and framework, for the Thai rubber industry supply chain have been developed. The results of solving GHG emissions minimization objective are presented and discussed

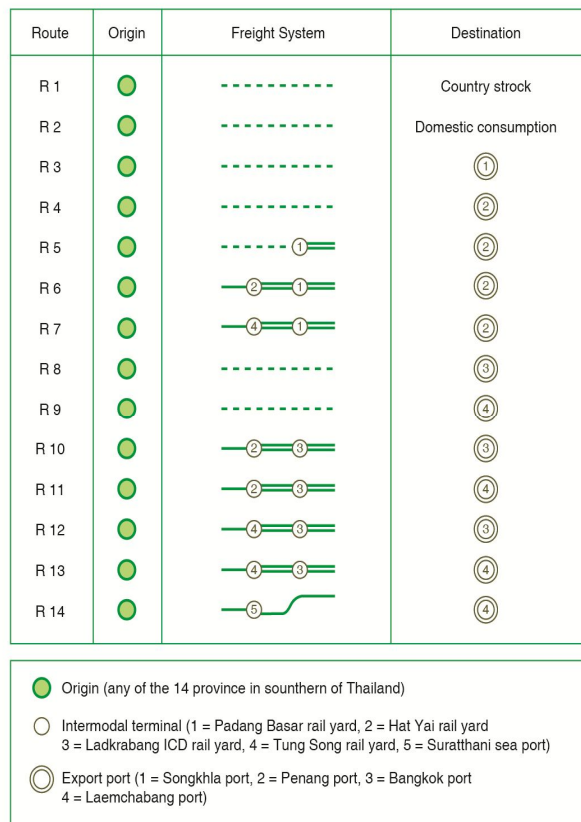
## APPENDIX

**Table 1: Green supply chain model for the Thai rubber industry notations**

<b>Set</b>		
$i \in I$	Set of provinces	
$r \in R$	Set of regions	
$p \in P$	Set of primary rubber products	
$s \in S$	Set of rubber farmer sizes	
$t \in T$	Set of truck types	
$g \in G$	Set of trader groups	
$f \in F$	Set of factories	
$e \in E$	Set of intermediate rubber products	
$a \in A$	Set of gateway nodes	
$b \in B$	Set of intermodal freight routes	
$d \in D$	Set of domestic destination and exporting port	
<b>Decision Variables</b>		
$X_{i,p,t,s}$	Amount of primary rubber product $p$ produce from farmer size $s$ in province $i$ transported by truck type $t$ to trader group $g$	
$Y_{i,p,t,s}$	Amount of primary rubber product $p$ from trader group $g$ in province $i$ transported to factory $f$ to produce intermediate rubber product $e$ and then subsequently transported to gateway node $a$	
$Z_{a,b,d,e}$	Amount of intermediate rubber product $e$ from gateway node $a$ transported by intermodal freight route $b$ to domestic destinations and exporting port $d$	
<b>Data and Parameters</b>		
$SC_{i,s}$	Aggregated primary rubber cultivation capacity of farmer size $s$ in each province $i$	
$TGC_{g,p}$	Aggregated trader group capacity of a given trader group $g$ for primary rubber	
	product $p$ in each province $i$	
$FC_{f,e}$	Aggregated factory production capacity of intermediate rubber product $e$ in a given factory $f$	
$DNC_a$	Aggregated gateway node capacity in a given gateway node $a$	
$FRC_b$	Aggregated freight route capacity in a given freight route $b$	
$DE_{a,d}$	Aggregated demand of intermediate rubber product $e$ at destination $d$	
<b>Environmental Parameters</b>		
$ER_{s,p}$	Greenhouse gas emission from farmer size $s$ to process primary rubber product $p$	
$ET_{s,t}$	Greenhouse gas emission from transport primary rubber products from farmer size $s$ to trader group $g$ by truck type $t$	
$EG_{g,p}$	Greenhouse gas emission from trading primary rubber product $p$ in trader group $g$	
$ET_{g,f}$	Greenhouse gas emission from transport primary rubber product from trader group $g$ in province $i$ to factory $f$	
$EF_{f,e}$	Greenhouse gas emission from factory $f$ to process intermediate rubber product $e$	
$ET_{f,a}$	Greenhouse gas emission from transport intermediate rubber products from factory $f$ to gateway node $a$	
$ET_{a,b}$	Greenhouse gas emission from transport intermediate rubber products from gateway node $a$ to freight route $b$	

$EM_{i,j}$	Greenhouse gas emission from transport via freight route $i$
$ET_{i,j}$	Greenhouse emission from transport intermediate rubber products from freight route $i$ to destination $j$

**Table 4: The fourteen transportation route of the Thai rubber industry southern corridor**



**Table 2: The rubber product greenhouse gas emissions**

Intermediate rubber product	Greenhouse gas emissions (Ton CO <sub>2</sub> -eq / ton product )
Latex concentration ( LTX )	0.54
Ripped- smoke sheet ( RSS )	0.66
Block rubber ( STR20 )	0.70

Source : Jawjit et al. 2010

**Table 3 : Greenhouse gas conversion factors for each transportation mode**

Transportation mode	Greenhouse gas conversion factors (kg. CO <sub>2</sub> -eq / ton-km)
Truck 4 wheels, 7 ton full by weight	0.3105
-0% loading	0.2676
-50% loading	0.1825
-75% loading	0.1399
-100% loading	
Truck 10 wheels, 16 ton full by weight	0.5851
-0% loading	0.0964
-50% loading	0.0685
-75% loading	0.0529
-100% loading	
Truck 18 wheels, 32 Ton full by weight	0.8629
-0% loading	0.0798
-50% loading	0.0525
-75% loading	0.0408
-100% loading	
Maritime deep sea shipping (container shipment)	0.0107
Inland waterway shipping (short sea shipping, container shipment)	0.0446
Rail transportation	0.01111

Source : Thai LCI Database ( TGO 2012 )

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# **CLOSED LOOP SUPPLY CHAINS: A SYSTEM DYNAMICS MODEL FOR ANALYZING SUSTAINABLE BUSINESS POLICIES FOR SHARED PARTNERS**

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## **ABSTRACT**

In this paper we develop an end-to-end model of a closed loop supply chain, and analyze it from the perspective of all partners in the chain. In particular, we model the lifecycle of consumer electronics good and implement a systems dynamic (SD) model to examine the interactions among different segments of the closed loop. Our focus is on economic viability of partners in this shared chain, which is a key ingredient for environmentally sustainable behavior and policies. Our results highlight the product and market policies that create positive revenue streams for all stakeholders in the chain for the closed loop to be economically and environmentally sustainable.

## **INTRODUCTION**

Research in closed loop supply chains have garnered significant importance, which mainly has a coordinated focus on combining the forward and reverse logistics of the supply chain (Guide and Wassenhove 2009, Atasu et al 2008). There are significant areas of interest in various applications, which may include modeling the forward and reverse logistics of clothes and apparel, tracing the lifecycle of a consumer product like a mobile phone, and the manufacture, recycling and remanufacturing of industrial products such as aircraft engines (ReCellular Jan 2007, Debo et al. 2006). The requirement of companies working within Europe include adherence to legislation such as WEEE (which stands for treatment of Waste from Electric and Electronic Equipment), which have spurred further interest in designing closed loop supply chains. Such businesses frequently have multiple partners along the supply chain, which handle different aspects of the manufacture, refurbish and recycling of electronic products (Debo et al 2006, Georgiadis et al 2006, Guide and van Wassenhove 2003, Guide et al. 2003, Guide 2000). These partners may share information resources as well as physical infrastructure, and the viability and business decisions of one determines the profitability of the other partners downstream. This suggests that decisions made by one partner in the supply chain may have important and complex impact on others along the chain (Fleischmann et al 2002, Teunter and Vlachos 2002, van der Laan et al 1999, Thierry et al 1995). In such situations, it is critically important to model and study these decision parameters on their integrative impact on the partners in the chain, with a major focus on sustainability of processes from a business perspective.

In this paper we develop a system dynamics closed loop supply chain model aiming to address these conflicting business and environment sustainability issues. In particular, our research focuses on the dynamics among the different segments of the closed loop, namely the product manufacturer and its product design and marketing strategies/policies, the different types of consumers and their product preferences, including the length of product ownership, and return, recycling and refurbishing mechanisms that impact the players at the downstream of the supply chain.

## MODEL

We model a problem scenario of a high value consumer electronic product with a short lifecycle, such as a mobile phone or a laptop. Such products usually have high material cost, and are environmentally unfriendly if disposed off quickly. Recycling has been a relatively new phenomenon in such goods, since margins from recycling are significantly lower than new product sales, leading to few recycling options. Hence such a consumer product, if not designed and marketed with an overall goal of sustainability from an environmental as well as business perspective, may lead to environmentally unfriendly business and supply chain cycles. For such a product, a new product manufacturer produces the product that is first adopted in the market by “market leaders” and subsequently by “followers”. The new product stays in the market for a period of time, where some consumers may return the product before its natural end of life. Such returns are reprocessed and brought back into the market as refurbished products, which may be preferred by “follower” consumers over the new product depending on market conditions. Other returns may be processed for recycling, where components are broken down to their elemental states for a restart of the manufacturing process. Products that are returned at the end of their natural life may be processed for refurbishing or recycling depending on the product design and condition (Figure 1).

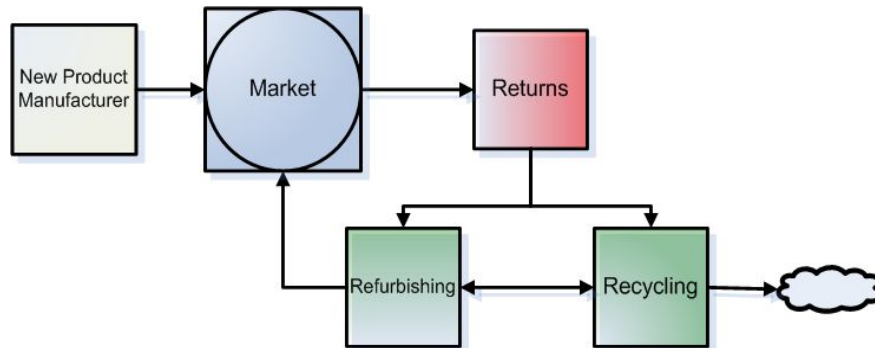


Figure 1: Overall Research Scenario and Model of Shared Resources

Each of these process areas described above presents a complex set of interrelated problems, which can usually be taken in isolation and solved to optimality. For example, marketing and pricing models exist for demand modeling and diffusion of new products in the marketplace; operations models have been proposed for logistics management; product design models suggest the lifecycle and associated costs of new and refurbished products; and consumer behavior research provide a guidance for the attractiveness of new versus refurbished products, and the impact of pricing and product design decisions. However for such a complex and interrelated decision making problem that involve multiple shared resources, an approach that optimizes the different components of the problem space may not provide a generalizable and overarching understanding of the dynamics of the system.

The parameters and decision variables of the model studied here is described in Figure 2. Model parameters include (Bass 1969) i) rate of innovators or market leaders in the system ( $\alpha$ ), ii) rate of imitators or followers ( $\beta$ ), iii) perceived product depreciation rate relative to new and refurbished products ( $\delta$ ), iv) price of new product ( $p_n$ ), and v) price of refurbished product ( $p_r$ ). By definition, innovators buy and use only new products (Bass 1969), while imitators may buy and use new or refurbished products. The decision variables include i) return rate of new products by innovators, termed end of life (EOL) return rate for innovators, ii) EOL return rate for imitators, iii) EOL return rate for refurbished products, iii) return to refurbish rate, iv) refurbish to recycle rate, v) leak rate of new products from innovators (return rate before designed end of life), vi) leak rate of new products from imitators, and vii) leak rate of refurbished products.

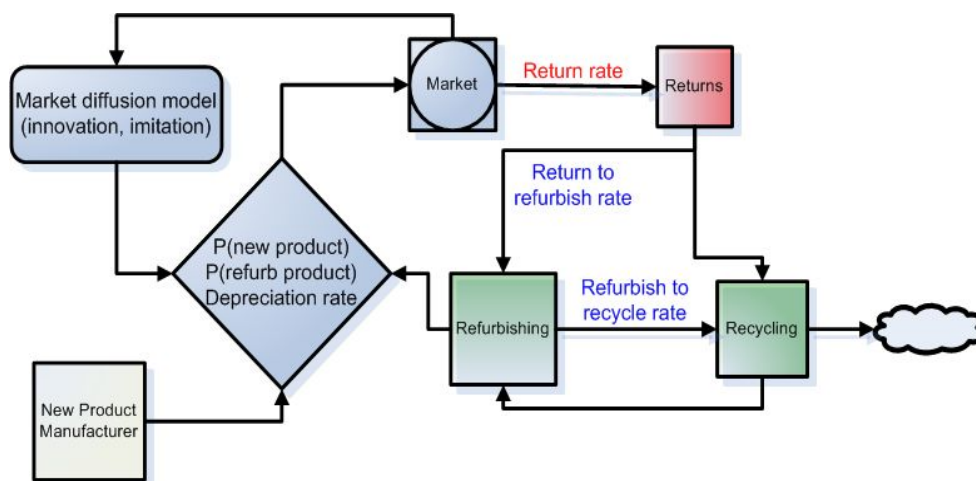


Figure 2: Decision Parameters of the Dynamic Model

The objective of the research is to study the integrative impact of the decision variables on the number of new and refurbished products in the market, the revenue impact on new product manufacturer, refurbisher and recycler, and the profitability and business sustainability of the refurbisher and recycler under various market and product design scenarios. While environmental sustainability of the supply chain is an important consideration, we argue that environmental sustainability goals should be modeled and subsumed into business sustainability, which are the true drivers of decision making for firms. For example, an economically sustainable refurbishing policy for a high-technology consumer product can be engineered to provide environmentally friendly benefits, and not necessarily vice versa.

We propose and implement a system dynamics approach to study the problem space and generate policy insights for managing the overall closed loop chain partners. System dynamics models have been used extensively to study complex phenomena that can be modeled quantitatively and may also contain qualitative constructs. It is well-suited for complex analytical models such as ours which have no closed form solutions, and may have non-linear and multiple level interactions among problem parameters (Georgiadis and Vlachos 2004, Dutta 2001, Morecroft and Sterman. 2000, Sterman 1987, 2000). An integrated approach that incorporates quantitative models developed in the literature, along with well-known models of the components of the overall supply chain, would provide rich insights into the decision making process. Our work is unique in addressing a holistic approach that includes initial pricing and sales of products, designing products for remanufacture and specified recycling rates, and looking at a holistic revenue stream of initial retailers, recyclers and remanufacturers.

## RESULTS AND DISCUSSION

The system dynamics model is validated using both qualitative as well as quantitative approaches. For each component of the model, we define causal loops based on existing literature, and test the partial model results to validate it. For the overall model, we plot the results for various output measures and compare them with those of published models and public data (where available). These provide confidence on the robustness and validity of our model.

Figures 3a and 3b show sales of new products and refurbished products sold to imitators, under price differentials of 0.1, 0.4 and 0.7, and perceived product differentiation between new and refurbished products ranging from 0.1 to 0.9. We see that for a given imitator rate (beta), perceived product differentials have a small positive effect on new product sales, and have a significant negative effect on refurbished product sales. The drop in sales of refurbished products continues even with price differentials that favor the refurbished products ( $p_n - p_r$ ). This suggests that perceived product differentials have a greater influence on refurbished product sales than price advantages. It would be important for product designers and marketers to develop public awareness campaigns for their products that aim to have a high proportion of refurbished sales for sustainable development.

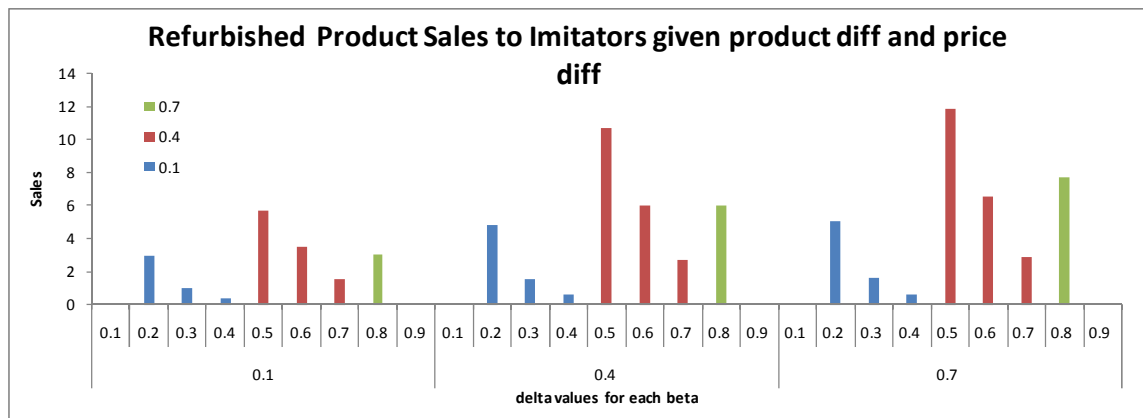


Figure 3a: New Product Sales to Imitators

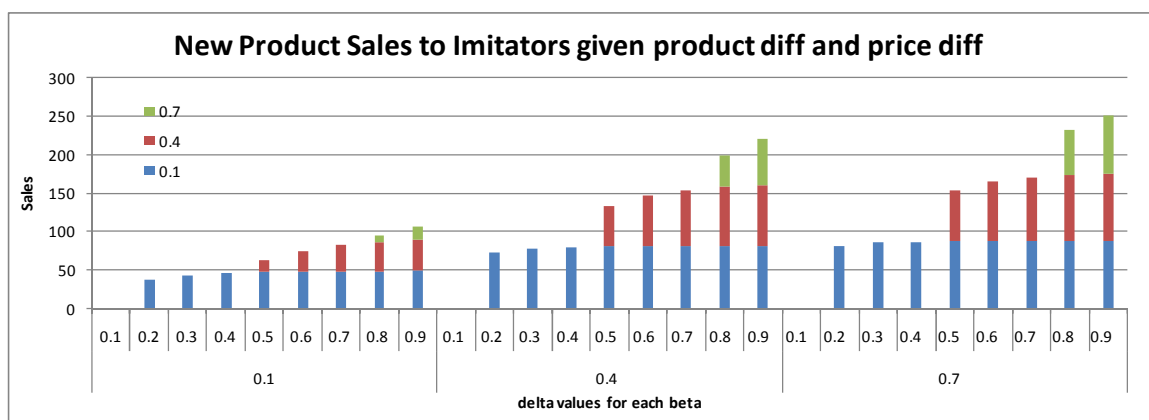


Figure 3b: Refurbished Product Sales to Imitators

We now turn our attention to the refurbish rate from returns and its impact on a sustainable business policy. Figure 4a shows that, as expected, the refurbish rate does not have an appreciable impact on new product sales, however it positively impacts sales of refurbished products, primarily through availability of refurbished products in the market (Figure 4b). As in the previous scenario (Figures 3a and 3b), refurbish sales is negatively affected by the perceived product differential. Hence perceived product differentiation is seen as a significant driver of consumer choice in the marketplace.

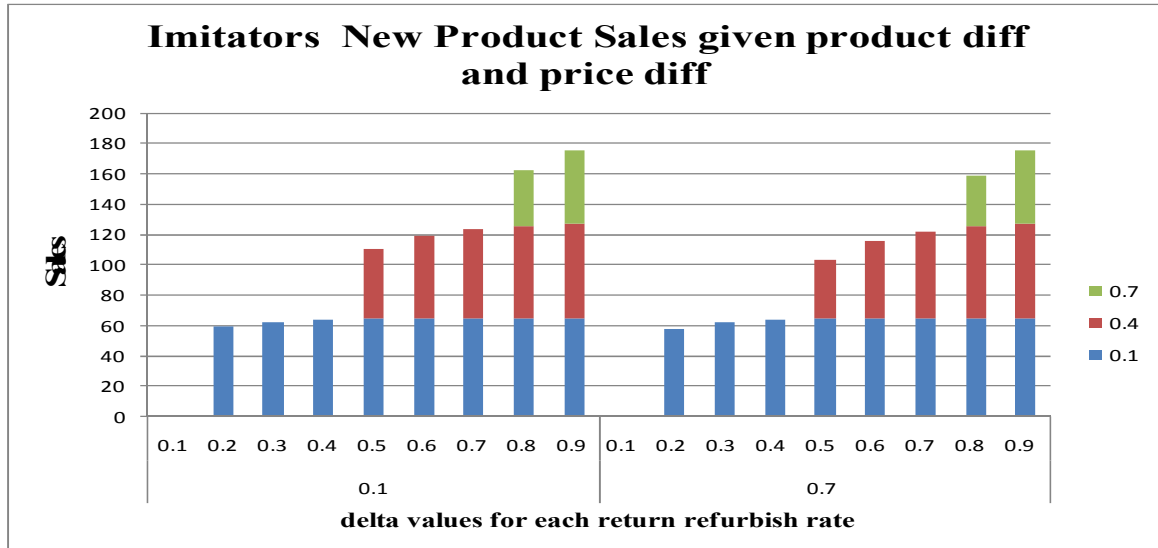


Figure 4a: Impact of Refurbish Rates on New Product Sales to Imitators

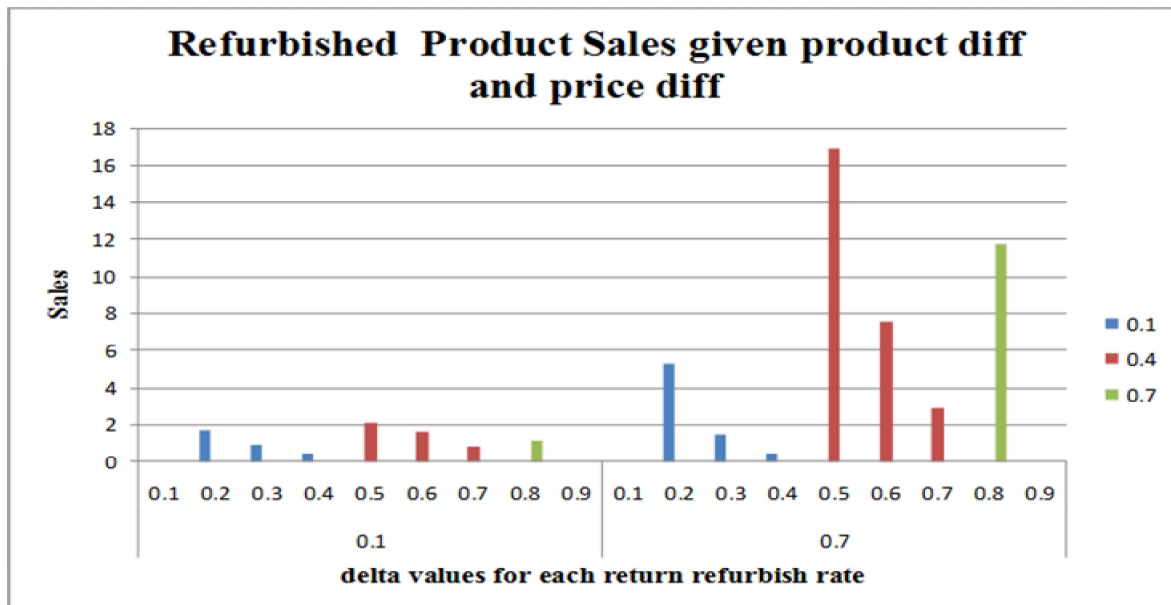


Figure 4b: Impact of Refurbish Rates on Refurbished Product Sales to Imitators

## CONCLUSION

We develop a holistic model of a closed loop supply chain, and analyze it from a consumer electronic goods perspective. We do not focus on any one particular element of the closed loop supply chain – rather we consider all partners and investigate their dynamic interactions. Our focus is on economic viability of partners in this shared chain, which is a key ingredient to sustainable behavior and policies. We develop a system dynamics closed loop supply chain model aiming to address these conflicting business and environment sustainability issues. Business sustainability will also need to include strategies for environmental sustainability. Consequently, on one hand, products that cannot be refurbished should be responsibly recycled, and on the other hand, business must also consider the second-hand market value of their products as they design the products. This is because consumers' perceived value of refurbished products can affect the sales and end-of-life management of the new product (Kwak et al. 2012).

In future research, we will show additional policy implications of product marketing and design choices on sales and sustainability of all market participants in such markets with shared resources.

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# **THE ROLE OF BUILDING RELATIONSHIPS WITH SUPPLIERS TO ENSURE THE SUSTAINABLE DEVELOPMENT**

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## **ABSTRACT**

The purpose of this research paper is to present the role of sustainable development in the building of partnerships with suppliers. While observing global trends one could notice that more and more suppliers are monitored in terms of fulfillment of the principles of sustainable development, following the economic aspects (requiring high technical quality, reliability of supply, price competitiveness, service support), more environmental aspects, as well as social ones (rules based on the idea of the Global Compact) by issuing special rules of conduct and ethical standards for suppliers. The article describes the results of empirical studies carried out in 170 enterprises operating in the Polish market. The aim of these studies was to identify the initiatives taken by the company in building partnerships with suppliers.

## **Introduction**

Ensuring quality of supply, companies require an ever closer cooperation on improving products and processes. Increasingly, corporate customers (especially manufacturers) are beginning to focus on the selection of key suppliers, forming long term relationships with them based on improving the technical quality of the product solutions. Many companies, especially those operating on an international scale, in order to even further reduce the risks associated with potential bidders, draw attention to aspects such as financial position, ethics of suppliers, and also pursued their pro-environmental actions. (Beamon, 2005; Seuring & Müller, 2008; Leire & Mont, 2010; French & Millan, 2010; Riedl et al., 2013; Holmen et al. 2013). Observing global trends one could notice that more and more suppliers are monitored in terms of fulfillment of the principles of sustainable development, following the economic aspects (requiring high technical quality, reliability of supply, price competitiveness, service support), environmental aspects, as well as social issues (principles based on the idea of the Global Compact) by issuing special rules of conduct and ethical standards for suppliers. These companies also implement awareness-raising projects (Supplier Responsibility Projects) and develop checklists (Supply Chain CSR Checklist) for self-assessment of providers. (Goebel et al., 2012)

## **Supplier assessment and building long-term partnership**

Companies which are business customers also notice that a prerequisite for good cooperation with suppliers is providing them with clear product specifications. (R.H. Ballou 2004; Fleiss and Becker, 2006). Clear examples of such behaviour may be observed in organizations with certified management systems, among manufacturers, in medium and large economic units and in global business entities. More and more customers on the market of companies notice efforts made by suppliers regarding building partnership marketing and their offering on-line technical advising, trainings, team-building meetings. They also often take advantage of the opportunity to place orders on-line. More and more companies improve relations with suppliers by means of joint research and development of new products and offering trainings to suppliers. (Leonidou, 2005) This is particularly emphasised by production companies and entities with foreign capital. Auditing suppliers and their implementation of an environmental management system is particularly noticeable in case of large business entities, companies with foreign capital and firms offering products on B2B market. An organization - upon purchasing all kinds of materials, equipment or services - should carefully define in its specification the subject of the order and send it to a qualified



supplier. In big enterprises the orders are placed by the purchasing department (the supply department). In small companies, in the majority of cases, there are some employees authorized to keep contacts with the suppliers (specialists/coordinators for purchases, managers of individual departments that are the users and warehouse managers). The criteria that may decide upon a periodical assessment of a supplier comprise: the level of the offered technical quality, favorable price conditions, timely deliveries, attractive payment terms, quality system in place, the level of the service quality and response to complaints. This evaluation is conducted on the basis of coefficients or score-related methods - supplier scorecard. Numerous companies also select their suppliers by means of evaluating their level of management, on the basis of the system certificates possessed by them (ISO 9001, ISO 14001), and also through periodical supplier audits. Some of the international enterprises as part of the supplier monitoring require regular reports concerning the progress in advancing their management system and conduct their documented monitoring through Performance Feedback Reports Cards that report data regarding cost-cutting, decreasing non-compliance, improvement of the process effectiveness and efficiency indicators, decreasing the energy use, shortening the time of the process realization cycles and optimization of the use of production capabilities. Many international companies, while qualifying suppliers, use the standards of their own invention. They constitute the general guidelines for the initial supplier qualification and those used for the periodical assessment. More and more often institutional clients (especially producers) begin to concentrate on the selection of key suppliers, shaping long-term relations with them based on the advancement of the technical quality of product solutions (running research and development projects together), reliability of deliveries (based both on their flexibility and shortening of the order cycle). These actions executed by both sides lead to decreasing costs. (Casadesús & de Castro, 2005; Khan & Creazza, 2009; Gosling et al. 2010; Cao & Zhang, 2011) Significant conditions shaping this partnership are the speed of information exchange and individualization of approach, e.g. by means of offering a wider and wider range of services by the supplier and getting involved in joint research and development of new products. (Johnsen, 2009) In many sectors of B2B market, one may notice a tendency towards limiting the number of suppliers that institutional customers cooperate with. (Hüttinger et al., 2012) Such a limitation of supply sources makes customers cooperate only with suppliers whose both reputation and image is, in their opinion, positive. This cooperation develops and often results in close relations between the supplier and the recipient. (Krause, 1997; van Weele, 2010) One of its aspects is precise compatibility of logistic systems of the partners. Due to close cooperation, partnership marketing in a supply chain significantly contributes to offering higher and higher technical quality as well as before-sale and after-sale service. It also ensures increased use of modern technologies for communication between the supplier and the customers. (Landeros & Monczka, 1989; Ellram, 1991; Foster 2010, Perols et al. 2013) Supplier Relationship Management is also an effect of effective and fast communication. Currently, in the majority of cases it assumes the form of the exchange of information with the use of electronic means of communication. (Fleiss and Becker, 2006) Many a time, such communication takes place long before the transaction is completed. Numerous suppliers place their product offer on their websites (in the form of catalogues or multimedia presentations), as well as their product certificates confirming the fact that they meet some specific quality requirements, forms of requests for quotation (concerning both standard and non-standard products). Electronic exchange of information also frequently takes place in case of post-sales activities. Many enterprises ensure this form of communication in order to provide the customers with the possibility to make complaints express their comments and take advantage of the technical advisory services.

### **Empirical study results**

The subjects of the empirical studies described in this paper were to identify the activities undertaken by the companies in terms of building the relationship with suppliers and business clients. The research was carried out in the fourth quarter of 2011. A

questionnaire was sent to 3224 enterprises operating in Poland. The response rate reached the level of 5.2 percentage (N=170). Major characteristics that were chosen to be used as predetermined variables: sector of the activity (production, services), number of employees, capital, scope of activity (international, home market), origin of capital (Polish, foreign) target market of delivering of the goods (B2B, B2C). The results of research indicated that companies building relations with suppliers most frequently indicated were periodic *indicators* for monitoring and *evaluating of suppliers*, and organizational requirements communicated to suppliers, possibility of orders on-line, audit at suppliers, implementation of ISO 9001 management system by suppliers. The results of the survey are presented in the tables below. (tables 1, 2, 3, 4, 5)

Table 1 Activities undertaken by the companies in terms of building the relationship with suppliers (percentage rate; comparison of organizations general and in term number of employees)

Activities undertaken by the companies in terms of building the relationship with suppliers	General N=170	Number of employees		
		- 50 N=58	51-250 N=74	over 250 N=38
Periodic <i>indicators</i> for monitoring and <i>evaluating of suppliers</i>	73.53	60.34	79.73	81.58
Products' specifications and organizational requirements communicated to suppliers	61.76	62.07	56.76	71.05
Possibility of orders on-line	48.24	55.17	43.24	47.37
Audit at suppliers	47.65	34.48	45.95	71.05
Implementation of ISO 9001 management system by supplier	45.29	37.93	47.30	52.63
Trainings offering by suppliers	35.53	31.03	32.43	39.47
Technical support offering by suppliers on-line	23.53	17.24	28.38	23.68
Implementation of projects related to the improvement of processes together with suppliers	20.00	20.69	18.92	21.05
Conduct joint research and development together with suppliers	18.82	17.24	18.92	21.05
Implementation of ISO 14001 management system by supplier	14.71	6.90	16.22	23.68

Source: author's research.

The results of these studies indicate that clients of companies that are on the B2B market require their suppliers to take action in the field of sustainable development. Enterprises building relationships with suppliers pay attention to the implementation of the management system compliance with ISO 9001, periodic evaluation and monitoring indicators of supplier performance, conducting projects related to improving processes and reducing operating costs (by assisting in the implementation of operational improvement tools), conducting on-line communication as well as joint research and development with suppliers in order to improve the quality of products and their positive impact on the environment. Analyzing the results of the study one could observe some differences between the various segments of the surveyed enterprises. Enterprises with foreign capital employing more than 250 workers more often than small and medium-sized companies build relationships with suppliers are focused on clearly defined products' specifications and organizational requirements communicated to suppliers and audit at suppliers. Firms employing more than 50 employees, more often than small companies pay attention to the periodic *indicators* for monitoring and *evaluating of suppliers* and implementation of quality management system conform to ISO 9001 standard as well as implementation of environmental management system conform to 14001 standard by suppliers. For small businesses especially those from the service sector, when it comes to the relationship with partners, the possibility of orders on-line is very important.

Table 2 Activities undertaken by the companies in terms of building the relationship with suppliers (percentage rate; comparison of organizations in term of sector)

Activities undertaken by the companies in terms of building the relationship with suppliers	Sector	
	Production N=115	Services N=55
<i>Periodic indicators for monitoring and evaluating of suppliers</i>	71.30	78.18
Products' specifications and organizational requirements communicated to suppliers	61.74	61.18
Possibility of orders on-line	45.22	54.54
Audit at suppliers	56.52	29.90
Implementation of ISO 9001 management system by supplier	52.17	30.90
Trainings offering by suppliers	28.70	40.00
Technical support offering by suppliers on-line	22.61	25.45
Implementation of projects related to the improvement of processes. together with suppliers	20.87	18.18
Conduct joint research and development. together with suppliers	20.87	14.54
Implementation of ISO 14001 management system by supplier	16.52	10.90

Source: author's research.

Table 3 Activities undertaken by the companies in terms of building the relationship with suppliers (percentage rate; comparison of organizations in term number of scope of business activity)

Activities undertaken by the companies in terms of building the relationship with suppliers	Scope of business activity	
	International N=147	Home market N=23
<i>Periodic indicators for monitoring and evaluating of suppliers</i>	75.51	60.87
Products' specifications and organizational requirements communicated to suppliers	61.90	60.87
Possibility of orders on-line	47.62	52.17
Audit at suppliers	52.38	17.39
Implementation of ISO 9001 management system by supplier	48.98	21.74
Trainings offering by suppliers	31.97	43.48
Technical support offering by suppliers on-line	23.81	21.74
Implementation of projects related to the improvement of processes. together with suppliers	22.45	4.35
Conduct joint research and development. together with suppliers	20.41	8.70
Implementation of ISO 14001 management system by supplier	14.97	13.04

Source: author's research.

Table 4 Activities undertaken by the companies in terms of building the relationship with suppliers (percentage rate; comparison of organizations in term of origin of capital)

Activities undertaken by the companies in terms of building the relationship with suppliers	Origin of capital	
	Foreign N=36	Polish N=134
<i>Periodic indicators for monitoring and evaluating of suppliers</i>	75.00	73.13
Products' specifications and organizational requirements communicated to suppliers	72.22	58.96
Possibility of orders on-line	41.67	50.00
Audit at suppliers	66.67	42.54
Implementation of ISO 9001 management system by supplier	50.00	44.03
Trainings offering by suppliers	36.11	32.84
Technical support offering by suppliers on-line	30.56	21.64
Implementation of projects related to the improvement of processes. together with suppliers	25.00	18.66
Conduct joint research and development. together with suppliers	27.78	16.42
Implementation of ISO 14001 management system by supplier	13.89	14.93

Source: author's research.

Table 5 Activities undertaken by the companies in terms of building the relationship with suppliers (percentage rate; comparison of organizations in term of market of offered products)

Activities undertaken by the companies in terms of building the relationship with suppliers	Market of offered products	
	B2B. N=115	B2C. N=55
<i>Periodic indicators for monitoring and evaluating of suppliers</i>	72.17	76.36
Products' specifications and organizational requirements communicated to suppliers	62.61	60.00
Possibility of orders on-line	43.48	58.18
Audit at suppliers	51.30	40.00
Implementation of ISO 9001 management system by supplier	48.70	38.18
Trainings offering by suppliers	32.17	36.36
Technical support offering by suppliers on-line	19.13	32.73
Implementation of projects related to the improvement of processes. together with suppliers	18.26	23.64
Conduct joint research and development. together with suppliers	16.52	23.64
Implementation of ISO 14001 management system by supplier	18.26	7.27

Source: author's research.

The enterprises with foreign capital, building relationship with providers more often than the companies with domestic capital, concentrate on compliance with technical and organizational standards, technical support as well as conduct joint process improvement or research and development project with suppliers. Enterprises that offer their products on the B2B market target as well as producers evaluating cooperation with providers especially concentrating on auditing suppliers, and the implementation of quality and environmental management standards. The results of the study indicated that this

groups of firms much more than the others are concentrating on the implementation of sustainable development concept building their relationship with supplier through the improving quality and environmental impact of the products and processes.

### **The trends in building the relationship in supply chain**

Observing world trends, one may easily notice that recently suppliers have been monitored from the point of view of meeting the sustainable development requirements following economic aspects (demanding high technical quality, delivery reliability, price competitiveness, technical support), and often also environmental aspects and social aspects (principles based on the concept of the Global Compact). Furthermore, supplier Conduct Principles are defined. Regarding environment protection requirements, special emphasis is put on suppliers by Japanese firms which laid down detailed guidelines for suppliers. Many international concerns more frequently require from their suppliers (of materials for production, equipment, office materials, packaging) detailed proofs defining environmental goals, documentation, activities aimed at limiting resources consumption, employee trainings, reducing factors harmful to environment (resulting from processes e.g. gas emission, noise, vibration, waste), disseminating information on performance connected with environmental protection. (Ulaga & Eggert, 2006; Gunasekaran & Spalanzani, 2012; Hoejmose & Adrien-Kirby, 2012; Tate et al. 2012)

Attention while carrying out audits aimed at the evaluation of functioning of suppliers' environmental management is most often paid to the following elements:

- environmental culture which is connected with adopting the environmental policy, identification of environmental aspects and defining environmental goals and tasks;
- adhering to laws concerning environmental protection;
- supervising the system of environmental management by means of ensuring appropriate documentation (procedures /instructions, records) and resources (infrastructure, process technology, information systems appropriately qualified employees) as well as employing environmental indicators (e.g. related to energy consumption, natural resources, waste economy, pollution);
- internal and external communication;
- employee trainings;
- cooperation with suppliers in the area of environmental management (establishing criteria concerning qualification and monitoring suppliers from the point of view of their environmental operation).

While signing contracts with suppliers, a lot of international concerns also make them sign statements according to which they will be obliged to adopt principles included in clauses of so-called business practices (Statements on Business Practices). The enterprises often issue special behavior and ethical rules for the suppliers (Supplier Conduct Principles, Principles and Standards of Ethical Supply Management Conduct) as well as guidelines in respect of their implementation (Supply Chain CSR Deployment Guidebook, Purchasing Way), organize programs (Supply Chain Social Responsibility Programs), introduce projects (Supplier Responsibility Projects) and draft control lists (Supply Chain CSR Checklist) used for instance for self-assessment of contractors. Statements on Business Practices are connected among others with business operations accompanied by scrupulous observation of all binding laws and ethical standards, avoiding corruption practices and fighting against attempts to bribe domestic and foreign institutions employees, avoiding employee discrimination, protection of international human rights and responsibility for the environment. It is worth noticing that these requirements are not imposed on one party only (by means of forcing suppliers to meet them). More and more companies want to shape their image as a reliable partner (customer) and therefore draw up purchasing codes of ethics or customer and supplier good practice guides. (Foerstl et al. 2010; Goebel et al., 2012)

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## **A LOGISTICS NETWORK DESIGN FOR TIRE RECOVERY: A CASE STUDY**

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### **ABSTRACT**

We consider the problem of designing a network for the collection and reprocessing of used tires. The network consists of the used tires supply points, i.e. the initial collection areas, the collection centers where used tires are stored and sorted to be sent to the relevant facilities, the recycling and the remanufacturing facilities where used tires are recovered, and the demand points. Tire remanufacturing, commonly known as tire retreading, and tire recycling are very profitable, yet many companies who reprocess used tires mostly do either only recycling or only retreading. We investigate the profitability of adding a tire retreading facility into the logistics network for a company who originally does recycling only. The problem is formulated and solved as a mixed integer programming (MIP) model to find the optimal design that maximizes the overall profit. Numerical experimentations are conducted to see the effects of changing return parameters on the optimal design and profit.

**Keywords:** Tire retreading, recycling, reverse logistics, mixed integer programming

### **INTRODUCTION**

The volume of scrap tires generated is growing due to the increasing number of vehicles every year. Scrap tires are solid waste which may cause significant environmental problems if landfilled. Tires are highly structured rubber products, which take a long time to decompose. Around 65%-70% of a tire consists of rubber and the remaining part is composed of steel wire and textile fibres. Because of their complex composition, the disposal of scrap tires has both environmental and economic impacts. European Tire and Rubber Manufacturers' Association (ETRMA) has declared that 3.3 million tons of used tires were generated in 2011 which is equivalent to 255 million tires (ETRMA, 2013). This remarkable volume of used tires has attracted governments' attention, and many countries have regulations to encourage companies to recover used tires. Tire recovery, not only reduces the environmental issues such as pollution and depletion of landfilling capacities, but also contributes to the economy by regaining the value hidden in the used tires.

The commonly used tire recovery options include energy recovery, recycling and retreading (Ferrao et al. 2008). End-of-life tires can be combusted to produce thermal energy. The main user of end-of-life tires for energy recovery is the cement industry while the remainder is used by district heating or power plants (ETRMA, 2013). Sienkiewicz et al. (2012) state that combustion of tires is environmentally safer (i.e. emits much lower levels of pollutants) and generates higher energy than coal combustion. Apart from energy recovery, used tires can be recycled or retread depending on the condition of the tire layers. Retreading is a process that basically consists of replacement of the worn-out tread, which extends the life of the used tire. Beukering and



Jannsen (2001) indicate that 80% of the raw material and energy necessary for production of a new tire is saved and the disposal amount is reduced significantly with retreading. A tire can be retread multiple times as long as the casing integrity is guaranteed. A retread tire is considered to have the same road performance (i.e. the same mileage) as a new tire, yet it is sold for a price that is 30% to 50% less than a new tire (Ferrer, 1997). Hence, retreading is the most sustainable recovery alternative and has the highest economic value. Similarly, recycling is another commonly used tire recovery option, which is an economic way of supplying various materials such as granule, steel wire and textile fibers or carbon black, oil and gas depending on whether mechanical or chemical recycling processes are used. The resulting materials from tire recycling can be used in various applications including the production of new products such as cable, mat, conveyor belt, artificial turfs, road embankment, heat insulation, playgrounds. They are also used in civil engineering applications and as energy resources in various industries such as cement.

In most European countries, a regulation system known as producer responsibility system is adopted in order to gain the economic and environmental benefits of tire recovery. Under this system, tire manufacturers are obligated to collect back the used tires and control the tire recovery process to assure the highest possible recovery rate in the most economical way. Currently, the producer responsibility system is operated by 18 countries including Turkey (ETRMA, 2013). In Turkey, tire manufacturers founded a non-profit organization (LASDER), which authorizes some companies such as recycling companies, individual stockers or collectors to manage the collection and recovery of end-of-life tires in the most efficient way. Tire manufacturers in Turkey are obligated to collect a certain proportion of the used tires whose value is determined by the government based on the sales volume of new tires in the previous year. While this proportion was originally 30% in 2007, it has increased every year and reached 60% in 2012. In order to collect the used tires, potential collection points such as tire repair & maintenance shops, auto services etc. are visited, and then, collected tires are sent to tire recovery facilities.

This paper considers the design of a reverse logistics network for a Turkish company that currently does tire recycling only. The network design problem is formulated as a mixed integer programming model and solved for different scenarios in order to see the effects of the return parameters on the design and the profitability of the tire remanufacturing.

## **LITERATURE REVIEW**

Because of environmental and economic benefits of tire recovery, the utilization rate of scrap tires in various applications has increased in the last two decades. Fiksel et al (2011) compare the environmental benefits of different applications of scrap tires, which include the use of tire-derived fuel as substitutes for fossil fuels in the generation of energy in several industries, civil engineering applications using tire-derived aggregates, and ground rubber applications such as athletic/recreational facilities, molded products, asphalt production and tire retreading. Ferrer (1997) discusses the economic benefits of four applications of scrap tires that are heat generation in thermoelectric plants or in cement kilns, ground rubber applications, direct reuse in civil engineering works and recycling through pyrolysis.

For efficient product recovery management, it is essential to design a reverse logistics network that enables the used products to be collected and recovered in the most economic and sustainable way. Beamon and Fernandes (2004) consider the problem of designing a closed-loop supply chain which is formulated as a multi-period mixed integer programming model. Similarly, Benaissa and Benabdelhafid (2010) use a cost-minimization model for a multi-type product waste reverse logistics system.

While there is much published work on network design problems for product recovery in general, the studies that consider specifically tire recovery are very scarce. Sasikumar et al. (2010) use mixed integer non-linear programming to design a multi-echelon reverse logistics network for truck tire remanufacturing, which they illustrate through a case study in India. Dehghanian and Mansour (2009) develop a multi-objective mathematical programming model for scrap tire recovery network design that aims to maximize economical and social impacts, and minimize the negative environmental impacts simultaneously. A multi-objective genetic algorithm is applied to find Pareto-optimal solutions.

To the best of our knowledge, no study exists in the literature that evaluates the profitability of having both tire retreading and tire recycling facilities in the same logistics network. We investigate the profitability of opening a tire retreading facility for a company who originally does recycling only using a multi-period mixed integer programming model that finds the optimal network design.

**A LOGISTICS NETWORK MODEL FOR TIRE COLLECTION AND RECOVERY**

In this section, the problem of designing a reverse logistics network for tire recycling and retreading is described and formulated as a mixed integer linear program. The network, shown in figure 1, consists of the initial collection areas (i.e. the used tires supply points), the centralized collection centers where the used tires coming from initial collection areas are aggregated and sorted to be sent to the relevant facilities, the recycling and the remanufacturing facilities where the used tires are recovered, and the demand points for retread tires and the materials resulting from recycling, i.e. granule and steel wire.

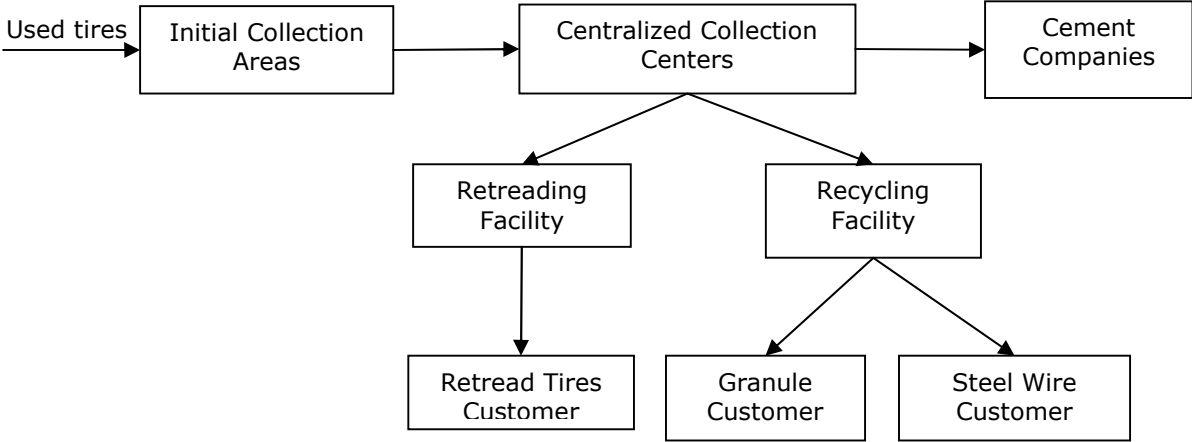


Figure 1: The logistics network for tire recycling and retreading

The collection of used tires is done typically as follows: Tires at the end of their life or after usage are usually sent first to places like tire repair & maintenance shops, vehicle dealers, etc., which are known as the initial collection points (ICPs) in the literature. Because the initial collection points can be numerous in real life, for an efficient modeling purpose, it might be better to group them based on their geographical location. A group of initial collection points is considered to form an initial collection area (ICA) in our model such that the supply amount of the ICA equals the total amount of tires supplied from the initial collection points in that group. Used tires at each ICA are transported to the centralized collection centers (CCCs), which are intermediate centers where the tires are inspected, cleaned and sorted as retreadable or recyclable based on their condition. Retreadable tires are sent to the retreading facility, and recyclable tires are sent to the recycling facility considering the capacities of these facilities as well as the demand for the corresponding resulting products. Any excess tires are sold to the cement companies for energy recovery.



$OC_{jt}^{CCC}$  : operating cost of CCC  $j$  in period  $t$   
 $OC_t^{RC}$  : operating cost of recycling facility in period  $t$   
 $Q_{it}$  : quantity of used tires received to ICA  $i$  in period  $t$   
 $TR_t$  : transportation cost/ton, unit distance from ICAs to CCCs, from CCCs to recycling facility or retreading facilities in period  $t$   
 $TR_t^{CF}$  : transportation cost/ton, unit distance from CCCs to cement facilities in period  $t$   
 $h_{nt}^{RC}$  : holding cost per ton per period for product  $n$  resulting from recycling in period  $t$   
 $d_{ij}^{CCC}$  : distance from ICA  $i$  to CCC  $j$   
 $d_{jl}^{RT}$  : distance from CCC  $j$  to retreading facility  $l$   
 $d_j^{RC}$  : distance from CCC  $j$  to recycling facility  
 $d_{jm}^{CF}$  : distance from CCC  $j$  to cement facility  $m$   
 $e_n$  : percentage rate of product  $n$  produced in recycling facility  
 $D_{nt}^{RC}$  : demand for product  $n$  produced in recycling facility in period  $t$

#### Variables

$V_{ijt}^{CRC}$  : Volume of tires sent from ICA  $i$  to CCC  $j$  in period  $t$   
 $V_{jlt}^{RT}$  : Volume of retreadable tires sent from CCC  $j$  to retreading facility  $l$  in period  $t$   
 $V_{jt}^{RC}$  : Volume of tires sent from CCC  $j$  to recycling facility in period  $t$   
 $V_{jmt}^{CF}$  : Volume of tires sent from CCC  $j$  to cement facility  $m$  in period  $t$   
 $V_{nt}^{RCP}$  : Volume of product  $n$  produced in recycling facility in period  $t$   
 $U_{nt}^-$  : Unsatisfied demand for product  $n$  at the end of period  $t$   
 $U_{nt}^+$  : Excess volume of product  $n$  at the end of period  $t$   
 $X_j = \begin{cases} 1 & \text{if CCC } j \text{ is opened} \\ 0 & \text{otherwise} \end{cases}$   
 $Y_l = \begin{cases} 1 & \text{if retreading facility } l \text{ is opened} \\ 0 & \text{otherwise} \end{cases}$   
 $Z = \begin{cases} 1 & \text{if recycling facility is operated} \\ 0 & \text{otherwise} \end{cases}$

#### Objective Function

The objective is to maximize the total profit over the planning horizon, which is calculated as the sales revenue from retread tires, granule, steel wire and used tires sold to cement companies (represented by expression 1) minus the total cost which includes setup costs for CCCs and retreading facilities (represented by expression 2), the retreading cost (represented by expression 3), operating costs for CCCs, retreading and recycling facilities (represented by expression 4), transportation costs between facilities (represented by expression 5) and holding cost for products resulting from recycling (represented by expression 6). The present values of all future costs are considered in the objective function.

$$\text{Sales Revenue} : \sum_t \sum_i \sum_j p_t^{RT} w V_{ijt}^{RT} + \sum_t \sum_n p_{nt}^{RC} (D_{nt}^{RC} - U_{nt}^-) + \sum_t \sum_m \sum_j p_t^{CF} V_{jmt}^{CF} \quad (1)$$

$$\text{Setup Costs} : \sum_j S_j^{CCC} X_j + \sum_l S_l^{RT} Y_l \quad (2)$$

$$\text{Retreading Cost} : \sum_t \sum_l \sum_j c_t^{RT} w V_{jlt}^{RT} \quad (3)$$

$$\text{Operating Costs} : \sum_t \sum_j OC_{jt}^{CRC} X_j + \sum_t \sum_j OC_{jt}^{RT} Y_l + \sum_t OC_t^{RC} Z \quad (4)$$

$$\text{Transportation Costs} : \sum_t \sum_j \sum_i TR_t V_{ijt}^{CRC} d_{ij}^{CRC} + \sum_t \sum_l \sum_j TR_t V_{jlt}^{RT} d_{jl}^{RT} + \sum_t \sum_j TR_t V_{jt}^{RC} d_j^{RC} \quad (5)$$

$$\text{Holding Costs} : \sum_t \sum_n h_{nt}^{RC} U_{nt}^+ \quad (6)$$

#### Constraints

$$\sum_j V_{jt}^{CCC} \leq Q_{it} ; \forall i \in I \text{ and } \forall t \in T \quad (7)$$

$$\sum_i V_{jt}^{CCC} \leq K_j^{CCC} X_j ; \forall j \in J \text{ and } \forall t \in T \quad (8)$$

$$\sum_i V_{jt}^{CCC} = V_{jt}^{RC} + \sum_i V_{jt}^{RT} + \sum_m V_{jmt}^{RF} , \quad \forall j \in J \text{ and } \forall t \in T \quad (9)$$

$$\sum_i V_{jt}^{RT} \leq \sum_i V_{jt}^{CCC} r, \quad \forall j \in J \text{ and } \forall t \in T \quad (10)$$

$$\sum_j w V_{jt}^{RT} \leq K_l^{RT} V_l , \quad \forall l \in L \text{ and } \forall t \in T \quad (11)$$

$$\sum_j V_{jt}^{RC} \leq K^{RC} Z , \quad \forall t \in T \quad (12)$$

$$V_{nt}^{RCP} = e_n \sum_j V_{jt}^{RC} , \quad \forall n \in N \text{ and } \forall t \in T \quad (13)$$

$$U_{nt}^+ - U_{nt}^- = U_{n,t-1}^+ - U_{n,t-1}^- + V_{nt}^{RCP} - D_{nt}^{RC} , \quad \forall n \in N \text{ and } \forall t \in T \quad (14)$$

Expression (7) represents that the total volume of used tires sent from ICA  $i$  to all open CCCs cannot exceed the supply amount of used tires by ICA  $i$  in period  $t$ . Expression (8) represents the capacity constraint for CCC  $j$  in period  $t$ . Expression (9) represents that the total volume of used tires received by CCC  $j$  in period  $t$  is sent all to the recycling facility, retreading facilities and cement companies. Expression (10) represents that the total volume of retreadable tires sent from CCC  $j$  to all retreading facilities in period  $t$  cannot exceed the total number of retreadable tires at CCC  $j$ , which is calculated considering the retreadable tire ratio  $r$ . Expressions (11) and (12) represent the capacity constraints for retreading facility  $l$  and recycling facility, respectively. Expression (13) calculates the total volume of product  $n$  produced in period  $t$  by considering the total volume recycled and  $e_n$ , which is the percentage rate of product  $n$ . Expression (14) represents the inventory balance constraints for product  $n$  for period  $t$ , i.e. net inventory (inventory on hand– shortages) at the end of period  $t$  equals the net inventory at the end of period  $t-1$  plus the amount of product  $n$  produced in period  $t$  minus the demand for product  $n$  in period  $t$ .

## NUMERICAL EXPERIMENTS

A case study of a tire recycling company in Turkey is considered in this section. Using the model formulated above, the profitability of entering into tire retreading business for this company is investigated. Due to privacy concerns, the identity of the firm is kept anonymous, and most numerical data corresponding to the model parameters (such as costs, selling prices, supply and demand amounts) cannot be provided for confidentiality.

The company is considering opening CCCs and retreading facilities for which the potential locations and corresponding capacity information are provided in table 1.

CCCs		Retreading facilities	
Potential Locations	Capacity (tons)	Potential Locations	Capacity (tons)
Sakarya	13,000	Sakarya	72,000
Gebze	10,400	Gebze	48,000

Bolu	7,800	Yalova	24,000
Yalova	4,680		
Catalca	2,600		

Table 1: Possible locations of CCCs and retreading facilities and the corresponding capacities

The recycling company under consideration is authorized to collect the used tires in the Marmara Region only, which is one of the seven regions of Turkey. Since there are hundreds of initial tire supply points (repair shops, auto services etc.) in the Marmara Region, for convenience they are grouped into 16 ICAs based on their geographical locations. ICAs supply used tires to any open CCCs, and CCCs in turn send the tires to open retreading facilities, the recycling facility or to any 11 cement plants.

The profitability of the tire recovery is investigated for different retreadable tire ratio values, and the results are compared to the current case where the company does recycling only and does not operate any CCC. The optimal profit and locations for CCCs and retreading facility to open corresponding to different scenarios are provided in table 2.

Optimal solution	Current case: Recycling only/ no open CCCs	Recycling and Retreading with open CCCs				
		Retreadable tire ratio				
		5%	10%	15%	20%	25%
Profit (million TL)	8.4	3	9.8	17.5	23.8	30.5
Additional profit	0%	-64.29%	16.7%	108.3%	183.3%	263.1%
CCCs to open	-	Sakarya, Yalova, Catalca, Gebze	Sakarya, Yalova, Catalca, Gebze	Sakarya, Yalova, Catalca, Gebze, Bolu	Sakarya, Yalova, Catalca, Gebze	Sakarya, Yalova, Catalca, Gebze, Bolu
Retreading facilities to open	-	Yalova	Gebze	Sakarya	Sakarya, Yalova	Sakarya, Gebze

Table 2: Optimal solutions for different scenarios

Results show that when the retreadable tire ratio is 5% only, it is less profitable (by around 65%) for the company to enter into tire retreading business. But if the retreadable tire ratio is 10% to 25%, the company can make an additional profit ranging from 16.7% to 263.1%.

## CONCLUSION

We study the problem of designing a logistics network for a tire recycling company who considers doing also tire retreading. The company does not currently operates a tire retreading facility nor a centralized collection center (CCC) where tires coming from initial collection areas are inspected and sorted. In order to determine the profitability of tire recovery (both recycling and retreading), a logistics network design problem is defined and formulated as a mixed integer linear program. The model determines where to locate CCCs and retreading facilities to maximize the overall profit. A numerical experimentation is done, where the model is solved for different scenarios corresponding to different values of retreadable tire ratio in order to see the effects on the optimal profit and design of the network, and the results are compared to current case for the company. Results show that tire retreading increases the profit by at least 16.7% compared to doing only recycling when the retreadable tire ratio is at least 10%.

As further study, the problem of tire recovery can be extended to cover all regions of Turkey in order to determine the economic value of tire recovery over the country. If the size of the resulting model is too large to be solved to optimality in a reasonable amount of time, development of a fast heuristic methodology that finds high-quality solutions is of interest.

## ACKNOWLEDGEMENTS

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# THE IMPACT OF CONSOLIDATION ON EXTERNALITIES IN URBAN FREIGHT TRANSPORT - THE CASE OF NOVI SAD

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## ABSTRACT

**Purpose** - Transport has a strong impact on people and environment, particularly in the cities, which has a high concentration of freight transport demand and population. However, the calculation and internalization of external costs from transport operations face many challenges, due to many difficulties to properly quantify them and then incorporate into the current service and product prices.

The identification and minimization of negative externalities from goods deliveries is an important aspect of sustainable urban transport development. Consolidation of urban deliveries is one of the city logistics concepts, which could contribute to minimization of such externalities and to the improvement of the resilience of urban supply chain on a whole. Thus, the research objective is to explore the impact of implementation of urban consolidation centres on external costs of intercity freight road transport. For that purpose, we use the case study of Novi Sad (Serbia).

**Design/Methodology/Approach** - We used the combination of literature research and a case study to explore the impact of urban consolidation centres on freight transport externalities. We considered several location options - scenarios and proposed the solution with minimum freight transport externalities.

The applied methodology consists of two main stages. Firstly, the externalities of current delivery system in Novi Sad were calculated, according to the results of recent traffic study. Secondly, we estimated external costs of city freight deliveries for different scenarios, which assume different number of urban consolidation centres in operation and varying delivery vehicles load factor utilization.

**Findings** - The comparison of scenarios results with the best solution for observed case study, and general conclusions are made for sustainable urban environment solutions, with regard to externalities from road freight transport and resilient urban supply chain.

**Research limitations/implications** - There are many limitations of presented research. Reverse freight flows are not included into the analysis. The certain approximations had to be applied in calculation, due to limited database on freight fleet and flows characteristics. The applied criterion in solving consolidation centre location problem is minimization of freight transport externalities. However, in the reality, this criterion is neglected in solving related problems and has to be combined with other criteria which are of crucial importance for planning location of city consolidation centre. Further research should also include other logistics externalities related with city consolidation problem.

**Practical implications** - It is very important for cost/benefit analysis to perceive all the costs caused and influenced by implementation of selected measures in practice. The research results could motivate the urban traffic planners, particularly in Serbian and Balkan environment, for further development of a comprehensive database necessary to include freight transport externalities into the freight consolidation centre studies.

**Originality/value** - The paper consider both, theoretical and practical approach to the development of sustainable urban freight transport systems. The usage of freight transport externalities as the criterion in solving of city consolidation location problem is almost neglected in the literature. The presented research aimed to stress this literature gap and contribute to bridge it.



## INTRODUCTION

City Logistics is “the process for totally optimising the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy” (Taniguchi et al., 1999). To address city logistics issues, European Commission provided handbooks and a best practice guides (Allen et al., 2009), where regulation measures are considered. Three main classes of measures are identified: goods vehicle access and loading approaches in urban areas (e.g. efficient usage of infrastructure; guidance on measures for goods vehicle access and loading in urban areas, technology in urban freight), principal issues involved in last mile solutions (e.g. home shopping via e-commerce) and principal issues associated with Urban Consolidation Centres (UCCs).

The introduction of freight consolidation centre is one of the measures proposed to reduce truck traffic and therefore externalities of freight transport in urban areas (Taniguchi et al., 1995). Research objective in this paper is to explore the possible impact of new urban consolidation centres on external costs of intercity freight road transport, by using a real example.

Data from recent studies and research papers on freight traffic in Novi Sad are used as input data for the calculation of external costs of freight transport. We compared the effects of introduced several location options with the current state without consolidation centres and propose the best solution, with least external costs.

The location of urban consolidation centre strongly contributes to external urban freight costs. It is the place where haulage and internal urban, short-distance flows are faced. Therefore, we explored the nature of both transport flows characteristics, identify possible locations and evaluate their impact on freight transport externalities.

The rest of paper is organized as follows. In the second Section, the literature review is given. The methodology is described in the third Section, main research results are presented in the fourth Section, while discussion and conclusion with final remarks are given in last two sections respectively.

## LITERATURE REVIEW

For the purpose of this research we use a broad definition of UCCs: “A UCC is a logistic facility that is situated in relatively close proximity to the geographic area that it serves, be that a city centre, an entire town or a specific site (e.g. shopping centre) from which consolidated deliveries are carried out within that area. A range of other value-added logistics and retail services can also be provided at the UCC.” (Browne et al., 2005, pp.4)

UCCs can benefit society and local authorities: (Lewis et al., 2010)

- Society and local authorities
  - ✓ Emissions affecting air quality (reducing PM and NO<sub>x</sub> by up to 100% for affected deliveries);
  - ✓ CO<sub>2</sub> emissions (by up to 55%);
  - ✓ Traffic congestion (up to 2,4 mil. € per UCC modelled in social benefit gains over 5 years);
  - ✓ Conflict between road users.
- Wider business interests
  - ✓ Maximising retail space and store staff (Up to 20% space expansion);
  - ✓ Reducing the delivery cost of „the final mile“ (commercial sensitivities mean that this is reported anecdotally rather than quantifiably);
  - ✓ Increasing the delivery window, generating opportunity for efficiencies in the distribution chain;
  - ✓ Meeting corporate social responsibility targets;

- ✓ For construction, helping to manage site congestion.

In order to gain the best possible effect by introducing the centre for urban freight consolidation, we should pay attention on its location. Optimization problems relating to the location of UCC's use to be modeled together with the routing of goods (Daganzo, 1996).

UCC construction affects an external cost of transporting goods in the city. An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group (European Commission, 2003). Transport externalities may be positive or negative (Belhaj et al., 2008). Implementation of different measures should maximize positive and minimize negative external costs. Also, externalities can be classified in two groups: main costs (quantitatively prominent) and secondary costs (costs that produce less important and/or not easily quantifiable effects). The main external costs are due to: (Mariano, G., 2010)

- **greenhouse gas emissions;** the greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>O, N<sub>2</sub>O, O<sub>3</sub>, etc.) are naturally present in the atmosphere and, therefore, are not assumed as pollutants from a technical point of view. However, the high concentration of these gases (mainly the CO<sub>2</sub>) increases the greenhouse effect, producing an increase in the average temperature of the planet, with serious climatic consequences.
- **air pollution;** transportation engines emit in the atmosphere some pollutants (SO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, CO, etc.). High concentrations of these gases cause damages to human health, buildings and cultivations.
- **noise;** transportation systems are noise sources. Besides disturbance, the noise produces health damages to residents in the more exposed zones.
- **accidents;** transportation accidents, mainly caused by road systems, are an important social problem. The costs produced by accidents are almost totally assumed as external, because the users do not perceive the accident risk and because the accident costs fall prevalently on collectivity (e.g. pain and suffering imposed to others).
- **congestion;** the increment of transportation costs due to congestion is not captured by the price system so the congestion costs are assumed as external, even if they are borne by users; they can be estimated by quantifying the users' lost time.

There are numerous secondary costs and the following are emphasized: water and soil pollution; landscape and nature damages; upstream and downstream effects; visual intrusion; separation effects; soil occupancy. (Mariano, G., 2010)

Currently, transport users do not pay all costs associated with their transport activities and, in particular, do not pay the costs they impose on the environment. The internalization approach ensures that each transport user pays the full social (private, environmental and other) costs associated to each transport operation. Therefore it is important to implement measures (e.g. freight consolidation) to reduce externalities in order to achieve an efficient and sustainable transport system with minimal costs.

## **METHODOLOGY**

With more than 300,000 inhabitants (Statistical Office, 2011), Novi Sad is the largest city and capital of the Autonomous Province of Vojvodina (Serbia). Novi Sad is a significant generator/attractor (origin/destination) of freight flows where road transport has a dominant role over other modes of transport. Significant contribution to that gives high

road network density and nearness of European route E-75 which belongs to series of main roads in Europe.

This paper analyze the impact of constructing UCCs on total external cost of freight transport in Novi Sad. Calculation of external cost will be carried out with respect to methodology and unit cost values of road transport given in Handbook (Maibach, M., 2008). External unit costs proposed in this handbook are in direct relationship with GDP of the analysed country. Unit cost values for Serbia are based on relation between Serbia's and EU gross domestic product (GDP) - Serbia's GDP was 36% of EU GDP in 2009.

### **Urban consolidation centre locations**

One measure that city traffic planners have implemented is a high restriction for entry of heavy duty vehicles into wider centre of the city ("city ring"). At first this measure was applied to all freight vehicles, but recently it is partly relaxed in the manner of allowing entrance to light duty vehicles (<5t). (Stojanovic et al., 2011)

Other measure that is considered includes a consolidation centre construction for city freight deliveries. Size of the city (over 300.000 inhabitants) represents an appropriate size for constructing logistics centre (Zečević, S., 2006). Optimized logistics centre can transfer the centre of gravity of freight transport from city centre to suburb, and alleviate traffic pressure in the centre and improve the efficiency of the whole urban transport system (Yang et al., 2005). UCCs analysed in this paper are dedicated only for road transport and they are smaller than the logistics centres. Therefore we can conclude that planning and construction of UCCs in Novi Sad is reasonable.

The location of the consolidation centres is a key element in enhancing the efficiency of urban freight transport systems and initializing relative supply chain activities sufficiently. There are several studies and research papers dealing with the goods delivery and location problems in urban area of Novi Sad in recent years. Public Enterprise "Urbanizam" carried out a conditions and feasibility study of the freight terminal in Novi Sad (PE "Urbanizam", 2004), where several terminal locations were analysed, according to macroeconomic traffic conditions. They concluded that the best possible solution for freight terminal construction is current location of Port of Novi Sad. Further, this study results were used as starting point of research and an analysis of city logistics terminal location was conducted with respect to micro-economic level (Velickovic et al., 2011). With regard to main freight flow attractors location in city and minimal average distance from terminal to these facilities, research resulted with (enhanced) conclusion that optimal terminal location is the same location that was identified as optimal in a previous study.

In our analysis, UCCs dedicated to road freight consolidation are proposed according to the several key guiding principles for the selection of locations:

- on the periphery of the city to intercept vehicles before they enter the urban area;
- with regard to positions of city entrance roads/intersections
- in close proximity to an appropriate delivery route in to the target area;

Based on aforementioned principles, we have identified three different locations, which were used in further analysis. The first location is in the western part of the city, second in the north, and third in the south-east part of the city (Figure 1). All three locations are on the periphery of the city, each is dedicated to serve certain city entrance roads (illustrated with black arrows on Figure 1, as well as it is assumed that delivery routes can be easily managed from each one of them.

The main limitation of criteria used in solving the UCCs location issue is that it did not reconsider location and size of freight attractors within the city (only overall proximity to

city contents is reconsidered). Additional effort should be made to include this criterion into location determination.

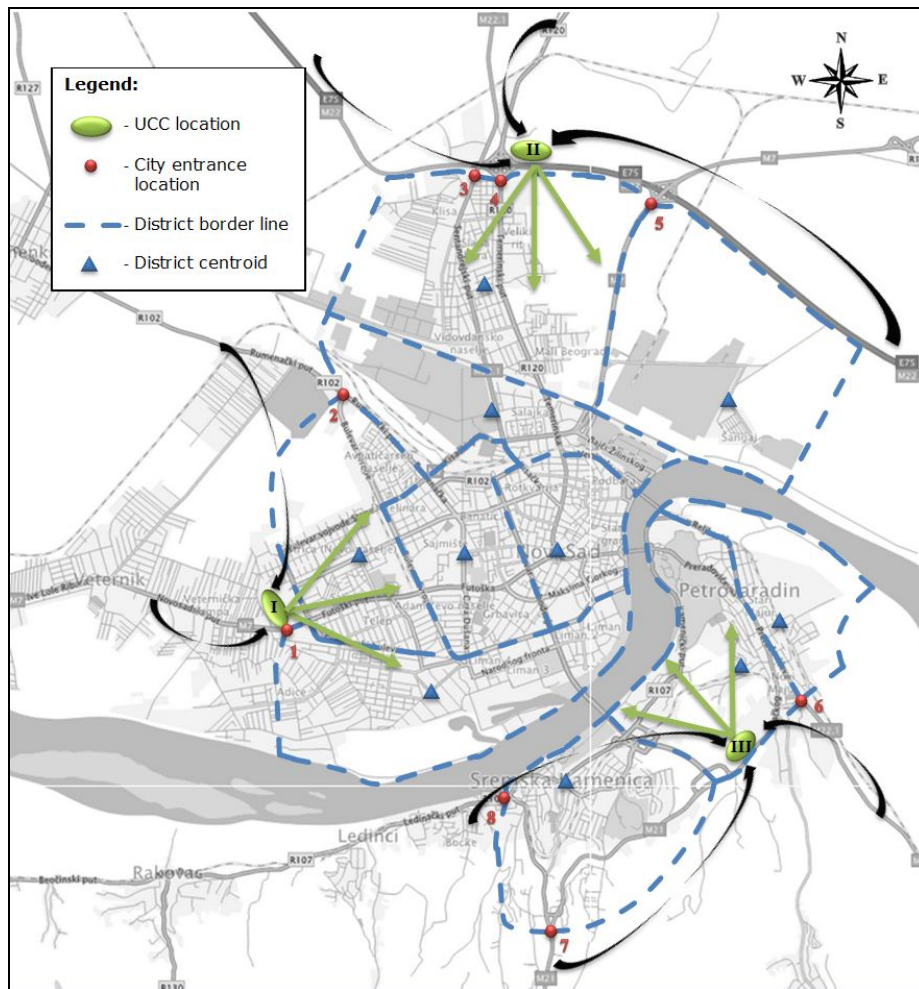


Figure 1. The map of the city of Novi Sad with the proposed locations of UCCs

### Data sources and definition of scenarios

Database about the traffic flows characteristics in Novi Sad, developed by a Public Enterprise „Urbanizam“ and Faculty of Technical Sciences (PE „Urbanizam“, 2009), represents input for this research. For freight consolidation we have considered only freight flows that are intended to supply city contents – destination flows (origin and transit flows were excluded because they have considerably less need for consolidation than destination flows from local perspective). It was found that total number of 3498 freight vehicles a day (69% of light duty vehicles and 31% of heavy duty vehicles) finishes trip at inner city area. High percentage of deliveries in peak hours (around 40% of total deliveries) impacts on city traffic congestion and creates serious problems which indicate the need for UCC construction. Freight vehicles in destination flows carry 10.285,12 tons of goods a day of which 38% is delivered in peak hour.

Externalities will be calculated based on average trip length and external unit costs of freight delivery vehicles. First, we need to calculate external cost of current freight distribution system and external cost of distribution with freight consolidation for all proposed options. Second, we can calculate external costs (by cost categories) of the best proposed solution and perceive changes in costs with regard to impact of UCCs on delivery vehicle load factors. The assumption is that the goods from UCCs are delivered with light duty vehicles with 3.5 tons of load capacity.

There are seven analysed options differed by number of UCCs in operation (locations I, II and III showed on Figure 1):

- Option A:** Freight distribution with one operating UCC (3 possibilities)
  - **A<sub>I</sub>** – one UCC at location I,
  - **A<sub>II</sub>** – one UCC at location II,
  - **A<sub>III</sub>** – one UCC at location III;
- Option B:** Freight distribution with two operating UCCs (3 possibilities)
  - **B<sub>I+II</sub>** – two UCCs at locations I and II,
  - **B<sub>I+III</sub>** – two UCCs at locations I and III,
  - **B<sub>II+III</sub>** – two UCCs at locations II and III;
- Option C:** Simultaneous operation of all three UCCs
  - **C<sub>I+II+III</sub>** – three UCCs at all three locations.

The vehicle routes are estimated by all-or-nothing technique. The all-or-nothing represents the simplest route choice method with assumption that all drivers consider the same attributes for route choice. After the routes are assigned the average trip lengths are calculated for current state and proposed options. Further effort focus on external costs calculation and comparison of calculation results.

## RESULTS - EXTERNAL COSTS CALCULATION AND COMPARISON OF DIFFERENT SCENARIOS

Firstly, the externalities of current delivery system in Novi Sad were calculated. Total externalities of current delivery system are **2791.45 €** in one day (Table 1). The externalities of proposed options are calculated and presented in relation to the current externalities in a way that total current state external costs are set to equal 100. The value of analysed option will be proportionally higher than 100 if the analysed externalities are higher than current costs and vice versa (Table 1). The crossed cells in Table 1 are eliminated options due to higher externalities than bolded ones.

Possibility	OPTION A			OPTION B			OPTION C
	I	II	III	I+II	I+III	II+III	I+II+III
<b>Index</b> ( <i>Current freight transport externalities</i> = 100)	101.03	<b>58.25</b>	97.68	59.28	98.71	<b>55.92</b>	<b>56.95</b>

Table 1. Comparison of different consolidation options

According to indexes shown in Table 1 the best results are obtained with two UCCs in operation (Option B<sub>II+III</sub>). However, it can be noticed that the highest decrease of externalities is caused by construction of UCC at Location II (Option A<sub>II</sub>). Consequently, we can assume that Option A<sub>II</sub> (with externalities relatively close to the best possibilities of both Option B and Option C) is the best solution due to the lowest application/implementation costs (construction of only one UCC).

Table 2 shows the comparative results of calculated external costs between the current state and the Option A<sub>II</sub>, with different load factor utilization for all categories of externalities. As one can see, congestion in peak hours causes the highest externalities and this is where consolidation of goods takes the most of its potential. Better utilization of load space of delivery vehicles result in bigger savings in externalities. If we assume that, in practice, the average use of load space is 60%, than total externalities will be one third lower compared to DN scenario.

<b>Current state</b> [€]	<b>Cost category</b>	<b>(Option A<sub>II</sub>) externalities for different load factor utilization of delivery vehicles from UCCs [€]</b>			
		40%	60%	80%	100%
233.05	Noise costs: Urban, day	150.48	138.28	132.18	128.52
1407.28	Congestion: Urban, peak	1173.71	985.98	892.12	835.80
524.84	Accidents: Urban	429.48	363.33	330.25	310.40
374.85	Air pollution: Urban, diesel	253.61	229.05	216.76	209.39
100.48	Climate change: Urban, diesel	72.11	63.76	59.59	57.08
119.21	Up- and downstream processes: Urban, diesel	85.30	75.50	70.60	67.66
31.73	Soil & water pollution: Urban	18.86	17.89	17.41	17.12
<b>2791.45</b>	<b>TOTAL</b>	<b>2183.55</b>	<b>1873.79</b>	<b>1718.91</b>	<b>1625.98</b>

Table 2. Daily external costs of intercity freight deliveries in Novi Sad – current state and impact of consolidation

## CONCLUSION AND RECOMENDATION

Freight transport in urban areas is the main source of many problems and additional (unnecessary) costs in recent years, especially road transport. To tackle road transport externalities in practice, several instruments can be used. The research presented in this paper confirms the expected result that city logistics measures, especially freight consolidation, can significantly reduce the negative externalities of intercity freight transport.

In order to analyse the impact of consolidation on externalities, we compared current state with proposed options, which include three locations of consolidation centres and alternatives with one, two or three consolidation centres, which means seven options in total. The consolidation with one centre (Option A<sub>II</sub>) was selected as the best. The main criterion to select the Option A<sub>II</sub> are the best results regarding external cost savings.

There are some serious limitations of the results presented in this paper:

- **lack of systematic data collection** - the inner city deliveries are not in the available;
- **impact of the consolidation centre is regarded only in terms of freight consolidation** - it does not take into account the potential reduction in distance traveled due to better organization and routing;
- **only one type of vehicles for freight delivery from centre is used** - fleet structure for freight deliveries from UCC can be more heterogeneous and adapted to goods and environment, that should lead to more cost reductions.

The research focus was only on external freight transport costs. However, the consolidation centre development assume great investments and the location(s) has (have) to be selected according to multicriteria analysis. Our research results could be used in such analysis performed by city transport planners. Related further research regarding urban freight externalities should focus on the following recommendations:

- take into account locations and size of freight attractors in the city while solving UCCs location problem;
- better cost savings can be achieved by using environmental friendly vehicles for deliveries from UCCs;
- improve the quality of results obtained in this paper by concerning the external cost of inner-city trips.

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## AN ENVIRONMENTAL FRIENDLY SOLUTION FOR COLD CHAIN

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### ABSTRACT

**Purpose** – This paper presents a model for the evaluation of the environmental impacts associated with the management of cold chain, considering the transportation and the storage activities. Moreover new equipment for the management of goods along the cold chain will be presented and its performances, in terms of emissions at different distribution stages, will be compared to those of traditional cold chain equipment. The new equipment is an active transportable insulated and refrigerated unit: its main advantage is the ability to be efficiently operative for transport activities using generic, non-refrigerated vehicles, as well as for storage in non-refrigerated warehouses.

**Design/methodology/approach** – A mathematical model based on costs and environmental impacts has been developed. Moreover a case study, regarding a novel refrigerated transportable unit, is presented so as to show the usefulness of the model proposed.

**Findings** – Environmental benefits and resource efficiency of the solution proposed are considered, as well as energy consumption reduction. Numerical analyses are also provided in order to demonstrate the efficiency of the solution considered compared to the traditional refrigeration technology involved in distribution chains.

**Originality/value** – There is limited research on the environmental impact of cold chain operations. The proposed model may help companies to pursue more sustainable practices in their cold chain activities.

**Keywords**– Cold chain, Refrigerated Equipment, Environmental impact

### 1. Introduction

The cold-chain accounts for approximately 1% of CO<sub>2</sub> production in the world (James and James, 2010), however this value may increase if global temperatures increase in the future. Using the most energy efficient refrigeration technologies, both for warehousing and transportation activities, it would be substantially possible to extend and to improve the cold-chain without any increase in CO<sub>2</sub> production, and possibly even with a decrease. In order to maintain the cold chain, the transport of perishable goods requires a specific logistic system, with specialized refrigerated vehicles and warehouses. Such system shows several limitations and is absolutely inefficient when shippers have to send small volumes of perishable goods (1 or 2 EU-pallet loads) to medium/long distance destinations. The main disadvantage is that refrigerated transport of small loads of perishable goods is offered only to main destinations, where refrigerated warehouses can be used as Hub to consolidate/split up full truck loads. For this reason, shippers are not able to satisfy all market requests. Moreover, the current offer for LTL (less than truckloads) services is “not efficient” from the environmental point of view for the following reasons:

- the small/medium size refrigerated trucks, used to pick up loads at producers and to deliver them to first refrigerated warehouses where the consolidation is made, are normally moving with a low load factor;
- fuel consumption and related emissions for the use of low load factor vehicles are high;
- high storage time frame spent in refrigerated warehouses (for consolidation / transshipment / split up of small loads) with related high electrical power consumption / emission.

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The system is also "inefficient" in terms of food hygiene, considering the several unload/load passages from trucks to refrigerated warehouses and vice versa, the need to sanitize large volumes and the risk of breaks in the cold chain. Finally, the system is also very expensive from the customer's point of view due to the investment in specialized vehicles and infrastructure. In particular, the cost per pallet moved can exceed from five up to nine times the cost for a non-refrigerated transport to the same destination.

Moreover, it should be observed that some logistic operators for limited distances already replaced refrigerated transport with passive containers (using eutectic plate or dry ice injection): due to the different target market (limited distance and limited time transportation) compared to the proposed system, the passive systems will not be used as reference.

In this study we have developed a model for accounting the environmental impact of transportation and warehousing activities in the cold chain.

Moreover a new equipment that may significantly affect the traditional cold chain distribution operations will be presented. The developed model will be used for the environmental impact comparison of the traditional cold chain and the cold chain operating with the new equipment.

Main environmental benefits of the analysed solution compared with the traditional benchmark situation are:

- Power consumption reduction for storage and transport
- Refrigerant leakage decrease
- CO<sub>2</sub> emission reduction due to power consumption and refrigerant leakage reduction.

Most food products are perishable and their shelf life can be greatly affected by temperature conditions in the supply chain: time/temperature control becomes a critical issue in fresh food logistics, and the efficient and effective tracking of cold chain conditions is one of the main points to be addressed. In this context Montanari (2008) proposed structured frameworks to help managers in selecting the most suitable solution in order to minimise the logistic costs.

Coulomb (2008) confirmed that refrigeration sector will continue to expand and it is also partly responsible for ozone depletion and global warming. Therefore he claimed more research, in order to reduce its impact on the environment and simultaneously to maintain a high level of safety in the cold chain.

Tassou et al. (2009) provided a review of current approaches in road food transport refrigeration. Their analysis indicated that greenhouse gas emissions from conventional diesel engine driven vapour compression refrigeration systems commonly employed in food transport refrigeration can be as high as 40% of the greenhouse gas emissions from the vehicle's engine. Moreover they presented a set of recent research on the development and application of alternative technologies to vapour compression refrigeration systems that have the potential to reduce the overall energy consumption and environmental impacts.

Fitzgerald et al. (2011) argued that for individual refrigerated containers, approximately 19% of the energy use related to its journey is used for refrigeration purposes. Moreover they observed that approximately 18% and 61% of New Zealand's imported and exported food products by mass, respectively, required some form of refrigeration during transportation. Moreover they particularly discussed the greenhouse gas emissions of the refrigerated transport of apples from NZ to the UK and long-term storage of UK apples.

Merrick and Bookbinder (2010) addressed the environmental implications of vehicle emissions. Nonlinear expressions relating carbon dioxide (CO<sub>2</sub>) emissions to vehicle weight, and parameterized by trip length and average travel speed, were derived from published experimental data.

The rest of the paper is organised as follows. In Section 2 the proposed model for the environmental impact assessment of cold distribution chains is presented, for the traditional chain and for the alternative solution investigated. Numerical analyses are reported in Section 3 and finally Section 4 proposes some conclusions as well as further research directions.

## 2. Model for environmental impact assessment

In this paper we will only discuss the computation of energy, CO<sub>2</sub> emissions for transport activity, as well as of energy and CO<sub>2</sub> emissions related to storage activities, considering specific energy consumption and specific emissions.

Network configuration as well as customer demand, truck capacity and storage area capacity are considered as problem parameters, which are assigned.

### 2.1 Traditional refrigerated distribution chain

#### 2.1.1 Transport

Considering the traditional chain, a rigid lorry refrigerated vehicle is supposed to be used. Two configurations are also included in the analysis: long distance transport ("long") and multi-drop distribution ("multi"). Long distance transport vehicles are rigid lorries or semi-trailers that have a unique refrigerated cargo container, with only one opening door for load and unload activities: this kind of vehicles is usually loaded (unloaded) in a single operation, differently from multi-drop distribution vehicles, that enable to have more than one unloading operation: in fact, multi-drop vehicles usually have more than one refrigerated cargo container, each with an opening door: this makes possible the traveller to serve more than one customer (unloading point) in each shipment trip, at the cost of reducing total cargo capacity and of being less efficient in terms of energy consumption, due to higher refrigeration capacity required to counteract the infiltration loads during door openings at unloading points.

For the long distance transport an energy factor  $en_{long,mean}^T$  of 0.1067 kW per m<sup>3</sup> of available inside volume has been considered, while for the multi drop distribution the energy factor  $en_{multi,mean}^T$  is 0.1652 kW/m<sup>3</sup>. These values have been computed on the basis of the data published in DEFRA (2008).

The mean energy factor per m<sup>3</sup> of available inside volume related to transport by rigid refrigerated lorry, related to long distance configuration ( $en_{long,mean}^T$  expressed as kW/m<sup>3</sup>) and to multi-drop configuration  $en_{multi,mean}^T$  (kW/m<sup>3</sup>) have been computed as follows:

$$en_{long,mean}^T = \text{mean} \left\{ \frac{en_{long,L1}^T}{V_{L1}}, \frac{en_{long,L2}^T}{V_{L2}} \right\}$$

$$en_{multi,mean}^T = \text{mean} \left\{ \frac{en_{multi,L1}^T}{V_{L1}}, \frac{en_{multi,L2}^T}{V_{L2}} \right\}$$

As the considered electricity CO<sub>2</sub> equivalent emission factor  $en_{CO_2}^{ele}$  is 0.537 kg CO<sub>2</sub> eq./kWh [1], and the considered diesel fuel CO<sub>2</sub> equivalent emission factor  $en_{CO_2}^{diesel}$  is 2.668 kg CO<sub>2</sub> eq./litre [1], CO<sub>2</sub> equivalent emissions related to the TRANSPORT process considering the long distance configuration  $E_{CO_2}^{T,long}$  [kg CO<sub>2</sub> eq./(m<sup>3</sup>·hr)] and the multi-drop configuration  $E_{CO_2}^{T,multi}$  [kg CO<sub>2</sub> eq./(m<sup>3</sup>·hr)], respectively, can be computed as follows:

$$E_{CO_2}^{T,long} = en_{long,mean}^T \cdot \frac{V_{long}}{n^T \cdot V^F} \cdot en_{CO_2}^{ele}$$

$$E_{CO_2}^{T,multi} = en_{multi,mean}^T \cdot \frac{V_{multi}}{n^T \cdot V^F} \cdot en_{CO_2}^{ele}$$

where  $V_{long}$  ( $V_{multi}$ ) expressed in as m<sup>3</sup>, is the inside volume of the considered container, long distance configuration (multi-drop configuration),  $n^T$  is the considered number of SKUs loaded in the container and  $V^F$  is the volume of food (m<sup>3</sup>) related to each SKU (here an SKU is EU-pallet sized). CO<sub>2</sub> equivalent emissions  $E_{CO_2}^{T,long}$  and  $E_{CO_2}^{T,multi}$  are both expressed as kg of CO<sub>2</sub> equivalent per hour and per m<sup>3</sup> of refrigerated food volume.

#### 2.1.2 Storage

For the traditional chain, walk-in freezers are considered as storage environment.

For the calculations, in this document energy consumption factor is 0.3 kWh/m<sup>2</sup> ( $en_{mean}^S$ ) for walk-in freezers, while the considered CO<sub>2</sub> equivalent emission factor for electricity is 0.537 kg CO<sub>2</sub> eq./kWh (DEFRA, 2008).

CO<sub>2</sub> equivalent emissions related to the energy required for storage process  $E_{CO_2}^{En}$  (kg of CO<sub>2</sub> equivalent per hour and per m<sup>2</sup> of refrigerated food area) for walk-in freezers ( $n^S$  is the considered number of SKUs stored,  $A^F$  [m<sup>2</sup>] is the surface occupied by food and  $A^S$  [m<sup>2</sup>] is the total storage area) can be computed as follows:

$$E_{CO_2}^{S,En} = \left( \frac{en_{mean}^S \cdot A^S \cdot en_{CO_2}^{ele}}{A^F \cdot n^S} \right)$$

It is assumed for this study that the refrigeration system will employ R404a as refrigerant, and as a consequence also refrigerant leakage are calculated. A typical value for refrigerant consumption  $Co^{REF}$  is 3.5 kg per kW of refrigeration capacity and assuming 15% annual leakage of refrigerant (DEFRA, 2008), the CO<sub>2</sub> equivalent emissions related to the refrigerant leakage  $E_{CO_2}^{Ref,Leak}$ , as kg CO<sub>2</sub> eq. per m<sup>2</sup> of stored food per hour, can be computed as follows:

$$E_{CO_2}^{S,Ref,Leak} = \left( \frac{en_{mean}^S \cdot A^S \cdot Co^{REF} \cdot Leak^{REF}}{A^F \cdot n^S} \right)$$

$Leak^{REF}$  value (refrigerant leakage factor) can be assumed to be 0.00016 kg CO<sub>2</sub> eq. per kg of refrigerant per hour (see in Table 4.7 DEFRA report values for Frozen peas, 0.17 g CO<sub>2</sub> eq./((kg ·hr) and Frozen chips 0.15 g CO<sub>2</sub> eq./((kg ·hr)).

CO<sub>2</sub> equivalent emissions related to the storage process  $E_{CO_2}^S$  (kg of CO<sub>2</sub> eq. emissions per m<sup>2</sup> of food per hour) considering a walk-in freezer and refrigerant leakage can be computed as follows:

$$E_{CO_2}^S = \left( \frac{en_{mean}^S \cdot A^S}{A^F \cdot n^S} \right) \cdot (Co^{REF} \cdot Leak^{REF} + en_{CO_2}^{ele})$$

## 2.2 PORTABLE REFRIGERATED UNIT distribution chain

The PORTABLE REFRIGERATED UNIT is an active transportable insulated and refrigerated unit. The active mechanical refrigeration allows the required temperature to be maintained for more than 24 hours for chilled products as well as for frozen. Main advantage of the system is its ability to be efficiently operative in the transportation using generic truck (providing energy supply with a simple 12/24 V plug) as well as for storage in a non-refrigerated warehouse (providing energy supply with a simple 110/230 V plug).

One of the direct advantages of the PORTABLE REFRIGERATED UNIT is the ability to ship different classes of goods (refrigerated and non-refrigerated) on the same truck.

First of all, it should be underlined that the baseline existing on the market, that is the benchmark for comparing the proposed solution, will be represented by the traditional refrigerated transport using refrigerated trucks (with cooling equipment).

### 2.2.1 Transport

Considering the new chain, a rigid lorry vehicle is supposed to be used. As PORTABLE REFRIGERATED UNIT heat load generated is non-negligible, then it is assumed that a ventilation system of the cargo is used.

Each PORTABLE REFRIGERATED UNIT (U) has an 1.920 m<sup>3</sup> internal volume, and a 3.960 m<sup>3</sup> external volume, with an external plant area of 1.8 m<sup>2</sup>, corresponding to 0.96 m<sup>2</sup> of food.

Concerning the ventilation system of the cargo, it is assumed that the energy consumption of one unit of the system is 0.025 kW (air flow 180 CFM, weight 0.9 kg).

CO<sub>2</sub> emissions  $E_{CO_2}^T$  (kg of CO<sub>2</sub> eq. emissions per m<sup>3</sup> of food and per hour) can be computed on the basis of the energy consumption of a single PORTABLE REFRIGERATED UNIT  $en^{PORTABLE REFRIGERATED UNIT}$ , which value is 0.216 kW (DANFOSS BD220CL, 4000 RPM,

-20°C), and adding the contribution of the ventilation system (involving  $v$  units per  $m^3$  of container inside volume, each corresponding to  $en^{vent}$ , kW, power); the electricity emission factor related to CO<sub>2</sub> equivalent emissions ( $en_{CO_2}^{ele}$ ) value is 0.537 kg CO<sub>2</sub> eq./kWh.

$$E_{CO_2}^T = \left[ \left( \frac{en^{vent} \cdot v \cdot V}{n^T} \right) + en^{PORTABLE REFRIGERATED UNIT} \right] \cdot \frac{en_{CO_2}^{ele}}{V^F}$$

where  $V$  ( $m^3$ ) is the internal volume of the considered container,  $n^T$  is the considered number of PORTABLE REFRIGERATED UNIT in the container and  $V^F$  is the volume of food ( $m^3$ ) related to each unit.

The main aim of the numerical analysis is to show the applicability of the environmental assessment model developed in the previous section. Moreover the relative performance of the PORTABLE REFRIGERATED UNIT compared to the traditional will be investigated on the basis of the typical data for refrigerated goods transportation.

### 2.2.2 Storage

Considering the new chain, no particular storage environments are required.

CO<sub>2</sub> equivalent emissions related to the STORAGE process  $E_{CO_2}^S$  (kg of CO<sub>2</sub> eq. emissions per  $m^2$  of food, per hour) can be computed by the energy consumption experienced by PORTABLE REFRIGERATED UNITS ( $en^{PORTABLE REFRIGERATED UNIT}$ , 0.216 kW) and the food area stored in each PORTABLE REFRIGERATED UNIT  $A^F$  (0.96  $m^2$  of food in each PORTABLE REFRIGERATED UNIT) and considering that the electricity emission factor related to CO<sub>2</sub> equivalent emissions ( $en_{CO_2}^{ele}$ ) value is 0.537 kg CO<sub>2</sub> eq./kWh.

$$E_{CO_2}^S = \left( \frac{en^{PORTABLE REFRIGERATED UNIT}}{A^F} \cdot en_{CO_2}^{ele} \right)$$

## 3. Numerical study

The main aim of the numerical analysis is to show the applicability of the environmental assessment model developed in the previous section. Moreover the relative performance of the PORTABLE REFRIGERATED UNIT compared to the traditional will be investigated on the basis of the typical data for refrigerated goods transportation. The following realistic data has been considered for the numerical study.

Parameter	Symbol	Unit of measure	TRADITIONAL		PORTABLE REFRIGERATED UNIT
			Long distance	Multi drop	
Energy factor (transport) <sup>(*)</sup>	$en^T$	kW/ $m^3$	0.1067	0.1652	0,1125
Cargo volume	$V$	$m^3$ _cargo	40	40	44
Max number of SKU to be loaded on truck	$n^{T,max}$	#	18	16	8
Unit food volume <sup>(*)</sup>	$V^F$	$m^3$ _food/S KU	1.92	1.92	1.92
Electricity CO <sub>2</sub> equivalent emission factor <sup>(*)</sup>	$en^{ele}_{CO_2}$	kg CO <sub>2</sub> eq./kWh	0.5370	0.5370	0.5370
Unit ventilation power	$en^{vent}$	kW	-	-	0.0250
Units of ventilation per cargo unit volume	$v$	#/ $m^3$ _cargo	-	-	0.1000
Motive power	$MP$	kW	368	368	368
Energy factor (storage) <sup>(*)</sup>	$en^S$	kW/ $m^2$	0.300		0.225
Storage area	$A$	$m^2$ _area	1000		1000
Max number of SKU to be stored in 1 area	$n^{S,max}$	#	270		150
Unit food surface <sup>(*)</sup>	$A^F$	$m^2$ _food/S KU	0.960		0.960

Refrigerant consumption <sup>(*)</sup>	$Co^{REF}$	kg <sub>REF</sub> /kW	3.500	-
Refrigerant leakage factor (annual) <sup>(*)</sup>	$Leak^{REF}$	kg CO <sub>2</sub> eq. / (kg <sub>REF</sub> ·hr)	0.00016	-

Table 1: Data for numerical study.

(\*) based on data reported in DEFRA (2008).

Figure 1 shows a comparison between the different types of transport in relation to CO<sub>2</sub> emissions calculated for different levels of saturation of the shipping volume available for the storage of food. In particular the emission of CO<sub>2</sub> is calculated with respect to the useful volume and to the transport time. The ratio of the emissions with respect to time is made for the purpose of making it independent of the path performed. From the figure it is clear how the technology PORTABLE REFRIGERATED UNIT is always the best with respect to different saturation; this is caused by the intrinsic modularity of the technology that always enables relative saturation of the compartment, and then the minimization of emissions for each unit transported. It should be noted that emissions considered are both those related to the carrier (negligible) and those related to refrigeration. The hyperbolic curve, typical for the other types of transport, becomes a straight line because of the fact that, as it is negligible the effect of the vector, the emission relative to the PORTABLE REFRIGERATED UNIT is proportional to the transported volume.

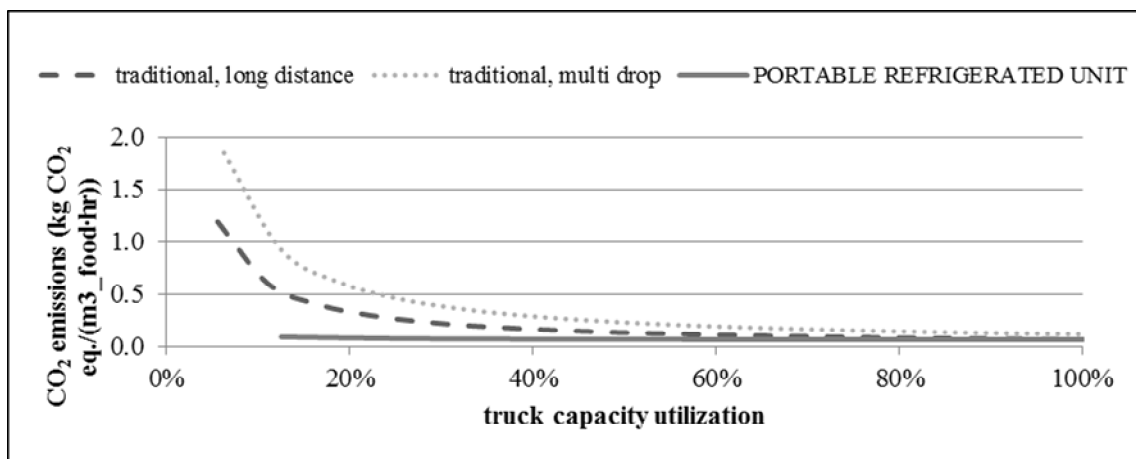


Figure 1: CO<sub>2</sub> emissions per m<sup>3</sup> of food per hour related to TRANSPORT process, for different levels of truck capacity utilization.

Figure 2 shows the comparison between the Short storage in traditional refrigerated warehouses and the refrigerated storage performed using the PORTABLE REFRIGERATED UNIT, in terms of CO<sub>2</sub> emissions generated. Also in this case, from the figure, it is clear how the PORTABLE REFRIGERATED UNIT option is always the best with respect to different saturations: even in this case, the modularity of this technology allows to refrigerate the strictly necessary volume, minimizing emissions.

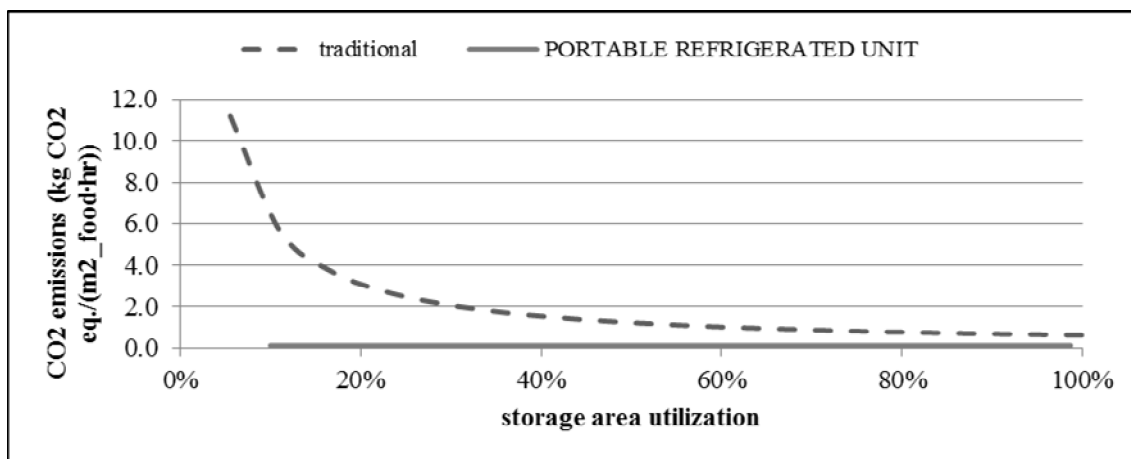


Figure 2: CO<sub>2</sub> emissions per m<sup>2</sup> of food per hour related to STORAGE process, for different levels of storage area capacity utilization.

#### 4. Conclusions and future work

There is limited research on the environmental impact of cold chain operations. The proposed model may help companies to pursue more sustainable practices in their cold chain distribution.

A numerical analysis is provided in order to demonstrate the efficiency of the solution considered compared to the traditional refrigeration technology involved in cold distribution chains.

The new solution for the refrigerated transport allows a consistent reduction of costs and CO<sub>2</sub> emissions. The economic and environmental benefits derived from modularity of the transport device that provides energy savings at different levels of volume moved. The other types of transport refrigeration do not have this kind of modularity, which would allow them to be efficient even when the volumes and frequency involves the unsaturation of the adopted vehicles. A similar analysis can be made with reference to the appropriate storage in warehouses, that covers the most important part both from the point of view of cost and environmental terms. Also in this case the cooling of an unsaturated volume entails higher costs per unit, avoidable with the PORTABLE REFRIGERATED UNIT solution that cools only the needed space. Also it should be noted that this type of technology never interrupts the cold chain because the unit is constantly chilled even when it is loaded/unloaded to the vehicle.

Finally it should be emphasised that the refrigerated transportation is significantly vulnerable to time, distance, modes of transportation and other transportation conditions. The analysed solution may overcome some of the problem that may arise, due to unpredictable events, in the traditional refrigerated transport and storage distribution chain. Thus the analysed solution may guarantee a more resilient cold chain.

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# **A STUDY FOR FORECASTING THE QUANTITY OF HOUSEHOLD WASTE - Improving Forecasting Precision by Selecting Period of Regression Data -**

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## **ABSTRACT**

Recently, it is confronted with social problems such as undersupply of refuse disposal equipment and landfill sites, in Japan. It is considered as one of factors causing these problems that the refuse displacement is increasing along with a recent economic growth. In Japan, refuse collection system is decided by an ordinance of a self-government body. In this study, refuse collection data of Hino city located in the suburbs of large city are used. In this city, there are some problems about distributing refuse collecting vehicles and workers of a cleaning trader. The purpose of this study is to propose the forecasting method of the quantity of household waste and to suggest improving of the refuse collection system. We proposed two kinds of forecasting methods of quantity of household waste by statistical method in previous studies. One of them is that the quantity of household waste of one day is forecasted by difference of quantity of household waste between a weekday and a holiday. The other of them is that the quantity of household waste is forecasted by a coefficient of correlation among a day of the week. In this study, to improve forecasting precision, useful selection of regression data period for forecasting is examined. As the result of this examination, we found out that forecasting precision is improved by excluding data of the day after event (festival and so on) and a typhoon from periods of regression data.

## **INTRODUCTION**

Recently, an environmental issue of a global scale is widely discussed in the world. Most of people are conscious of a possible remedy for environmental problem. Especially, CO<sub>2</sub> reduction is widely discussed. In Japan, it is confronted with one of social problems such as undersupply of refuse disposal facilities and landfill sites. It is considered as factors causing these problems that the refuse displacement is increasing along with a recent economic growth. In this study, these problems are picked up. In Japan, refuse collection system is decided by an ordinance of a self-government body. At the big city, therefore, a useful refuse collection system is required.

In this study, we adopt about refuse collection system at Hino city located in the suburbs of Tokyo. At the clean center of Hino city, there are some problems of refuse collection system. One of them is distributing refuse collecting vehicles and workers of a cleaning trader. Then, to improve this problem, we examine to forecast quantities of household waste per day. Especially, burnable waste is adopted in this study, because proportion of burnable waste in household waste is higher than other kinds of household waste. In previous studies, two kinds of forecasting method of quantities of burnable waste per day are proposed applying statistical analysis. Still using data of quantity of burnable waste per day are offered by Hino city hall. One of them is "the method of estimated difference of quantity between a weekday and a holiday". Other of them is "the method of a coefficient of correlation among a day of the week". The each forecasting method is described later. From some forecasting results, purpose of this study is to improve forecasting precision of proposed forecasting methods.

In this paper, following two matters are examined to improve forecasting precision. One of them is that factors or events which quantity of burnable waste of one day differs from that of other day are extracted, and such data of factors or events are excluded for forecasting. Other of them is that quantity of burnable waste is forecasted using data of the same period of previous years.

From next section, at first, refuse collection way and data of burnable waste at Hino city are described. And, our proposed forecasting methods of quantity of burnable waste are



explained. Next, improvement of forecasting precision is examined. Finally, forecasting results are shown, and forecasting precision is evaluated.

### REFUSE COLLECTION WAY OF BURNABLE WASTE AT HINO CITY

Hino city is small city located at the west of Tokyo as shown in Figure 1.

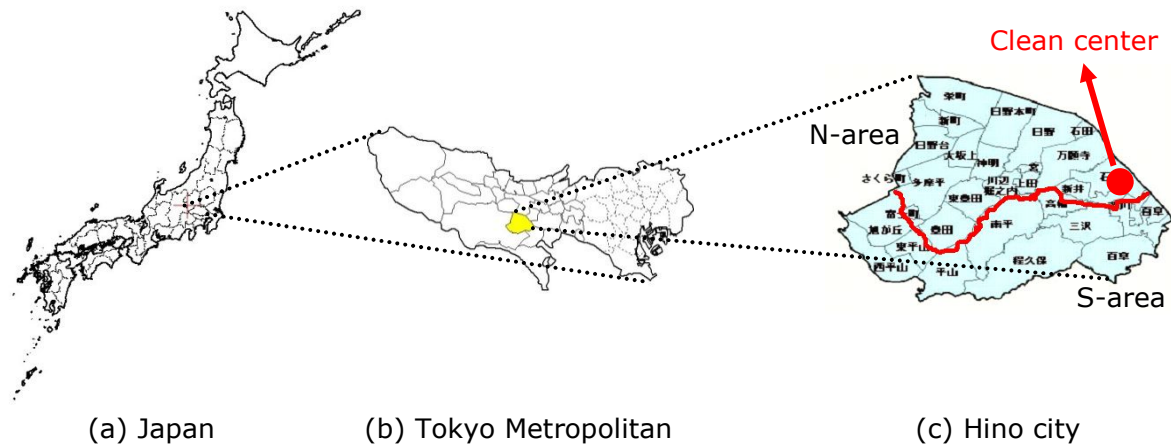


Figure 1: Location map of Hino city

She is consisted of 28 km<sup>2</sup> of area, 30 of towns and 1.8 billion of population. The clean center is located at the east of Hino city. Hino city is divided into two areas, north area (N-area; 0.9 billion of population) and south area (S-area; 0.9 billion of population), by a river which flows in this city (thick line in Figure 1(c)). Workers of cleaning trader which are authorized by Hino city collect burnable waste by using several kinds of refuse vehicles. Collected burnable waste is gathered to this clean center. Burnable waste of each area is collected twice a week by cleaning trader. A day of the week for a collection of burnable waste at each area is shown as follows.

- N-area: Monday and Thursday
- S-area: Tuesday and Friday

Residents put burnable waste at front gate of home at the morning of each collection day of burnable waste. Usually, twenty of refuse vehicles a day work to collect burnable. And, each refuse vehicle goes back and forth for several times in a day from the clean center to the decided collection service area.

### TENDENCY OF REFUSE COLLECTION DATA OF BURNABLE WASTE AT HINO CITY

In this section, tendency of refuse collection data of burnable waste which are offered by Hino city hall are pre-processed. The period of pre-processed refuse collection data of burnable waste is for a year (from Dec. 2010 to Nov. 2011). Transition of quantity of burnable waste per month is shown in Figure 2. In this figure, horizontal axis represents months, and vertical axis represents quantity of collected burnable waste. As shown this figure, quantity of collected burnable waste of each month is different. And, transition of quantity of collected burnable waste seems to tend the seasonal variation. It seems that quantities of collected burnable waste of summer become to be increased than that of other seasons. Still the reason why quantity of collected burnable waste of February is a little is that the collected frequencies of burnable waste are little. Next, transition of quantity of burnable waste of each day of the week is shown in Figure 3. In this figure, horizontal axis represents number of weeks, vertical axis represents quantity of collected burnable waste of each day of the week. No. 1 in this horizontal axis is set the first week in Dec. 2010. As shown this figure, although refuse collection service area is different, transition of quantity of burnable waste between Monday and Tuesday is similar. In the same way, that between Thursday and Friday is similar.

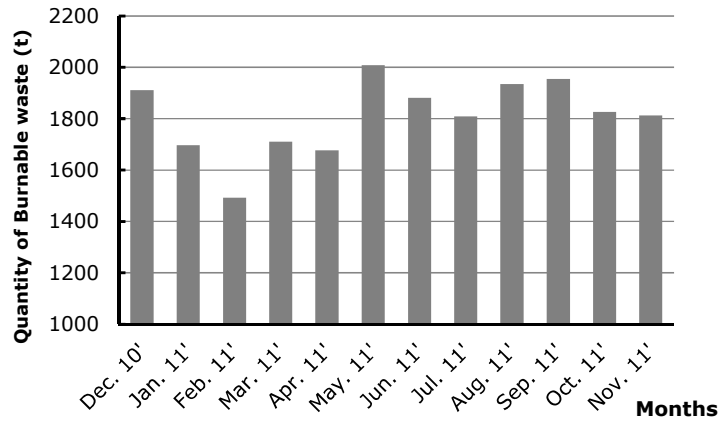


Figure 2: Totalled quantity of burnable waste of each month

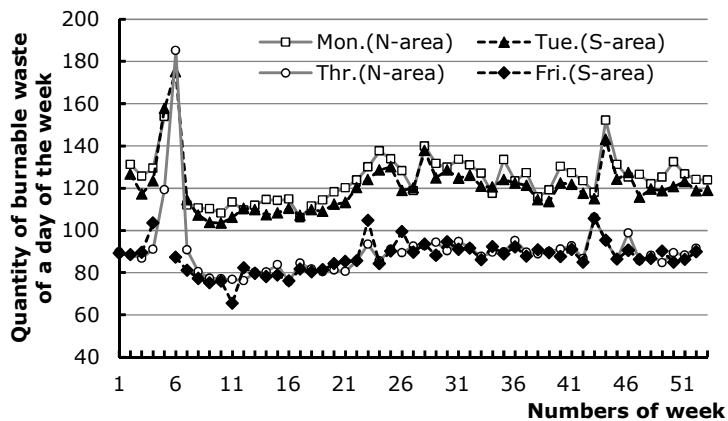


Figure 3: Quantity of burnable waste of each day of the week

### FORECASTING METHODS OF QUANTITY OF HOUSEHOLD WASTE

In this section, two kinds of proposed forecasting methods of quantity of household waste are explained briefly. One of them is “the method of estimated difference of quantity between a weekday and a holiday”, and the other of them is “the method of a coefficient of correlation among a day of the week”.

#### The method of estimated difference of quantity between a weekday and a holiday

In this sub section, one of proposed methods, “the method of estimated difference of quantity between a weekday and a holiday” (M.E.D.), is explained briefly. Although burnable waste does not collect every day by a cleaning trader, burnable waste is discharged every day. In this proposal method, discharged burnable waste per one day is estimated. And, quantity of discharged burnable waste at refuse collection day is forecasted. Firstly, following matters are assumed.

- Quantities of discharged burnable waste of every weekday are equal.
- Quantities of discharged burnable waste of every holiday are equal.
- Quantity of discharged burnable waste between a weekday and a holiday is different.
- A weekday means from Monday to Friday.
- A holiday means Saturday, Sunday and a national holiday.

The concept of this proposed method is following consideration. At N-area, a day of the week of collected burnable waste is Monday and Thursday. Quantity of collected burnable waste on Monday equals to quantity of totalled discharged burnable waste from Thursday in previous week to Sunday in this week. And, quantity of collected burnable waste on Thursday equals to quantity of totalled discharged burnable waste from Monday to

Wednesday in this week. That is, quantity of collected burnable waste on Monday is totalled quantity of discharged burnable waste for two weekdays and that for two holidays. And, quantity of collected burnable waste on Thursday is totalled quantity of discharged burnable waste for three weekdays. From this concept, the model formula is expressed in equation (1).

$$y_{ij} = a_{ij}x_{1j} + b_{ij}x_{2j} + \varepsilon_{ij} \quad (1)$$

Where,  $y_{ij}$  is quantity of collected burnable waste by cleaning trader on  $i$  of a day of the week,  $j$ th of the week.  $a_{ij}$  is frequencies of discharged burnable waste of a weekday on refuse collection day.  $b_{ij}$  is frequencies of discharged burnable waste of a holiday on refuse collection day.  $x_{1j}$  is quantity of discharged burnable waste of a weekday in  $j$ th of the week.  $x_{2j}$  is that of holiday in  $j$ th of the week.  $\varepsilon_{ij}$  is error term.  $i$  is a day of the week (1: Monday, 2: Tuesday, 3: Thursday, 4: Friday).  $j$  is numbers of week. In equation (1), estimated variables  $\hat{x}_{1j}$  and  $\hat{x}_{2j}$  of  $x_{1j}$  and  $x_{2j}$  are leaded. This equation (1) changes into equation (2).

$$\sum \varepsilon_{ij}^2 = \sum (y_{ij} - a_{ij}\hat{x}_{1j} - b_{ij}\hat{x}_{2j})^2 \quad (2)$$

$\hat{x}_{1j}$  and  $\hat{x}_{2j}$  are estimated by the least-squares method that  $\varepsilon_{ij}$  becomes minimum. In this proposed method, quantity of burnable waste of N-area and S-area is estimated separately. Therefore, the proposed forecasting formula of N-area and S-area is expressed in equation (3) and equation (4), respectively.

$$\frac{d}{d\hat{x}_{1j}} \sum (\varepsilon_{1j}^2 + \varepsilon_{2j}^2) = 0 \quad (3)$$

$$\frac{d}{d\hat{x}_{2j}} \sum (\varepsilon_{1j}^2 + \varepsilon_{2j}^2) = 0 \quad (4)$$

### The method of a coefficient of correlation among a day of the week

In this sub section, the other of proposed methods, "the method of a coefficient of correlation among a day of the week" (M.C.C.), is explained briefly. A correlation of collected burnable waste among each day of the week in same week or in previous week is shown in Figure 4.

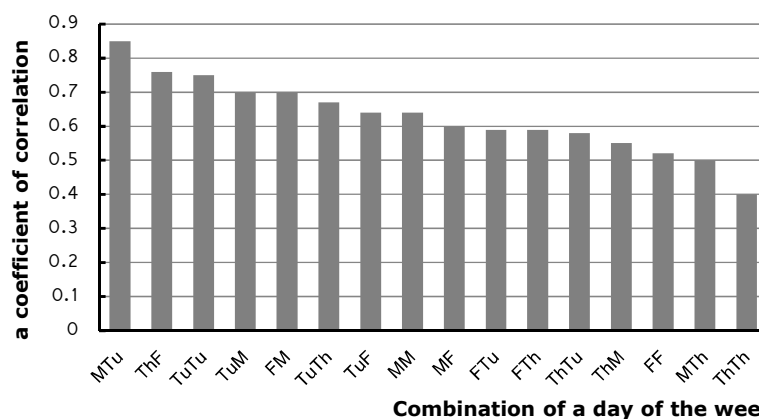


Figure 4: A coefficient of correlation with combination of a day of the week

In this figure, horizontal axis represents a combination of a day of the week, and vertical axis represents a coefficient of correlation. Combination of a day of the week "MTu" means a combination of Monday and Tuesday in the same week. Combination of a day of the week "TuM" means a combination of Tuesday in this week and Monday in previous week. Thus, about sixteen combinations of a day of the week, each correlation of quantity of collected burnable waste is analyzed. As shown in this figure, a coefficient of

correlation of combination "MTu", "ThF", "TuM" and "FM" becomes higher. These combinations of a day of the week are that refuse collection service area is different. The concept of this method is that quantity of burnable waste is forecasted using quantity of collected burnable waste of a day of the week which correlation of quantity of collected burnable waste becomes higher. From this concept, the procedure of this proposed method consists of following two steps. In Step 1, correlation analysis is performed using quantity of collected burnable waste of forecasting day of the week as subject variable and that of other day of the week as explanation variable. And, a day of the week which a coefficient of correlation approaches to 1 is selected. In Step 2, regression formula is deduced by single regression analysis using quantity of burnable waste of forecasting and selected a day of the week. This leded regression formula is the forecasting formula as expressed in equation (5).

$$y_{ij} = \alpha z_{ij} + \beta \quad (5)$$

Where,  $y_{ij}$  is forecasting quantity of burnable waste on  $i$  of a day of the week,  $j$ th of the week.  $z_{ij}$  is quantity of burnable waste of selected a day of the week on  $i$  of a day of the week,  $j$ th of the week in Step 1.  $\alpha$  is a partial regression coefficient, and  $\beta$  is an intercept in Step 2.

### EXAMINATION OF IMPROVEMENT OF FORECASTING PRECISION

In this section, improvement of forecasting precision is examined. In previous study, forecasting precision of "the method of estimated difference of quantity between a weekday and a holiday" is 3.45%. And, that of "The method of a coefficient of correlation among a day of the week" is 3.77%. In this study, to improve forecasting precision, following two matters are examined.

- Extraction of factors or events which quantity of burnable waste of refuse collection day differs from that of other refuse collection day
- Using quantity of burnable waste of the same period of previous years for forecasting

#### Extraction of factors or events which quantity of burnable waste of refuse collection day differs from that of other refuse collection day

In this subsection, it is examined that factors or events which quantity of burnable waste of refuse collection day differs from that of other refuse collection day. This concept is shown in Figure 5.

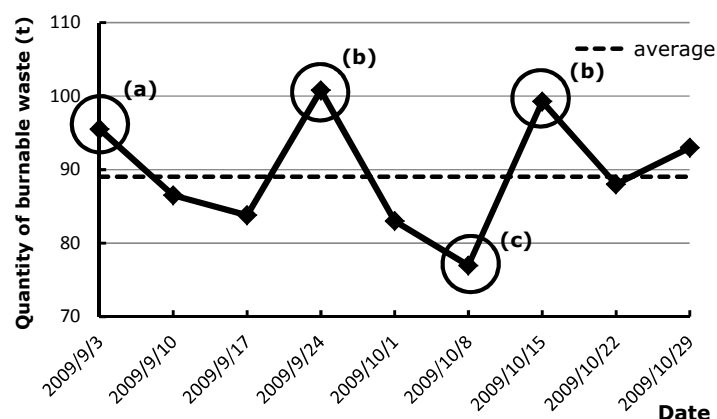


Figure 5: The concept of examination 1

In this figure, horizontal axis represents date, and vertical axis represents quantity of burnable waste. This figure shows transition of quantity of burnable waste on Thursday from 3<sup>rd</sup> September in 2009 to 29<sup>th</sup> October in 2009. A dotted line in this figure shows averaged quantity of burnable waste on Thursday from 2<sup>nd</sup> July in 2009 to 24<sup>th</sup> November

in 2011. As shown in this figure, there are four of refuse collection day that quantity of burnable waste is more than averaged quantity of burnable waste. In this figure, a characteristic of each refuse collection day is (a); the following day of typhoon, (b); the following day of a national holiday, (c); typhoon on the day. Thus, collection quantity of burnable waste is increased and decreased by weather conditions and events. From such conditions, it considers that these collection quantities of burnable waste are influencing the forecasting precision. Then, following six of characteristics conditions are extracted.

- Year end and new year (con.1)
- A national holiday (con.2)
- The following day of a national holiday (con.3)
- Typhoon or heavy rain on the day (con.4)
- The following day of typhoon or heavy rain (con.5)
- The following day of festival (con.6)

Thus, the data of quantity of burnable waste of these characteristic conditions are not used to forecast quantity of burnable waste as outliers.

### Using quantity of burnable waste of the same period of previous years for forecasting

In this subsection, it examined that the data of quantity of burnable waste of the same period of previous years is used for forecasting. This concept is shown in Figure 6.

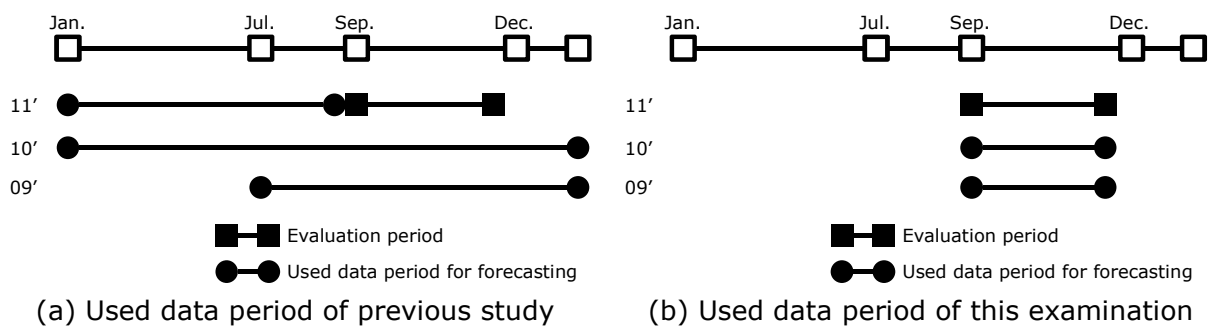


Figure 6: The concept of examination 2

In this figure, horizontal axis represents months, and vertical axis represents year. Here, evaluation period is assumed from 1<sup>st</sup> September in 2011 to 30<sup>th</sup> November in 2011. In previous study, quantities of burnable waste of evaluation period are forecasted using all acquired data. As shown in Figure 3, however, collected quantity of burnable waste is different through year, season or month. Moreover, it considers that collected quantities of burnable waste are similar at the same period of different year. Then, quantities of burnable waste are forecasted using data of same period of past year. Still following two patterns of past year are set.

- One past year (1-y)
- Many past year (m-y)

### FORECASTING RESULTS AND EVALUATION OF FORECASTING PRECISION

In this section, forecasting results of quantity of burnable waste are shown, and forecasting precision is evaluated.

#### The period of used data and evaluation for forecasting

In this paper, the used data period of collected quantity of burnable waste offered by Hino city hall and weather information are from 1<sup>st</sup> July in 2009 to 30<sup>th</sup> November in 2011 (for two years and five months). Weather information is acquired at web page of the Meteorological Agency. And, the evaluation period is from 1<sup>st</sup> September in 2011 to 30<sup>th</sup>

November in 2011 (three months). Therefore, it assumes that the data of collected quantity of burnable waste of evaluation period are not existed.

**Forecasting result of “The method of estimated difference of quantity between a weekday and a holiday”**

In this subsection, a part of forecasting result of “M.E.D.” assumed “con.1” is shown in Table 1.

Table 1: A part of forecasting result of “M.E.D.” assumed “con.1” (unit: t)

Date	Forecasting value	Actual value
2011/09/01(Thu.)	89.60	91.10
2011/09/02(Fri.)	89.94	87.60
2011/09/05(Mon.)	125.52	127.32
2011/09/06(Tue.)	122.52	121.70

As shown in table, forecasting quantity of burnable waste (“Forecasting value” in table) is increased and decreased as compared with actual quantity of burnable waste (“Actual value” in table). In the same way, each forecasting result is calculated by combination forecasting method and examinations (two kinds of forecasting methods (M.E.D. and M.C.C.), six kinds of factors or events (from con.1 to con.6) and two kinds of past year period (1-y and m-y)).

**Evaluation method of forecasting precision**

In this paper, evaluation method is expressed in equation (6).

$$d_{ij} = \frac{|y_{ij} - \hat{y}_{ij}|}{y_{ij}} \times 100 \tag{6}$$

where,  $d_{ij}$  is relative error ratio on  $i$  of a day of the week,  $j$ th of the week.  $y_{ij}$  is actual collected quantity of burnable waste on  $i$  of a day of the week,  $j$ th of the week.  $\hat{y}_{ij}$  is forecasting quantity of burnable waste on  $i$  of a day of the week,  $j$ th of the week. Actually, forecasting precision is evaluated using averaged relative error ratio in the evaluation period.

**Comparison of forecasting precision**

First, forecasting precision of M.E.D. summarized examination in evaluation period is shown in Table 2. In Table 2, horizontal column represents used data period, and vertical column represents examination items.

Table 2: Comparison of forecasting precision of M.E.D. in evaluation period (unit: %)

	All	1-y	m-y
previous study	3.45	-	-
con.1	3.58	3.15	3.38
con.2	3.89	3.74	4.05
con.3	2.64	3.47	3.33
con.4	3.45	3.17	3.20
con.5	3.34	3.05	3.33
con.6	3.63	3.06	3.04

In this figure, painted columns mean that forecasting precision becomes higher than forecasting precision of previous study. As shown in figure, it considers that forecasting

precision is improved by this examination in evaluation period. Especially, forecasting precision is affected by used data period for forecasting.

Next, forecasting precision of M.C.C. summarized examination in evaluation period is shown in Table 3. In Table 3, horizontal column represents used data period, and vertical column represents examination items.

Table 3: Comparison of forecasting precision of M.C.C. in evaluation period (unit: %)

	All	1-y	m-y
previous study	3.77	-	-
con.1	3.72	4.40	3.78
con.2	3.62	4.13	3.61
con.3	3.99	4.89	4.35
con.4	3.74	4.26	3.63
con.5	3.82	4.40	4.05
con.6	3.74	4.29	3.67

In this figure, painted columns mean that forecasting precision becomes higher than forecasting precision of previous study. As shown in figure, it considers that forecasting precision is improved by this examination in evaluation period. Especially, forecasting precision is affected by omitting outlier data for forecasting.

## CONCLUSION

In this study, improvement of forecasting precision for proposed forecasting method of collected quantity of burnable waste is examined. In this paper, two kinds of way are examined. One of them is that the data of collected quantity of burnable waste of characteristic conditions are not used to forecast collected quantity of burnable waste as outliers. In this examination, six kinds of characteristic conditions are extracted. Other of them is that the data of collected quantity of burnable waste of the same period of previous years are used for forecasting. In this examination, two kinds of period of previous years are set. From these examinations, we found out that forecasting precision of these examinations become higher than that of previous study in evaluation period.

In this study, however, obtained forecasting precision is not satisfied. In future tasks, the methods of correcting deduced forecasting formula are investigated.

Now, Hino city hall has been discussing to introduce the concept of our proposed forecasting method into work of refuse collection. It, however, is difficult to change regulations at present. Still, it is reported by the staff of the clean center at Hino city that "the method of a coefficient of correlation among a day of the week" is useful method for practical refuse collection of burnable waste. Especially, it is useful that there is correlation between collected quantity of burnable waste on Tuesday and that on Monday. For example, if collected quantity of burnable waste on Monday is more than averaged that, it is useful to change distributing refuse collection vehicles and workers on Tuesday.

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Hino city hall (<http://www.city.hino.lg.jp>).

The Meteorological Agency ([http://www.jma.go.jp/JMA\\_HP/jma/index.html](http://www.jma.go.jp/JMA_HP/jma/index.html)).

# **IS THERE A REAL DEVELOPMENT IN SUSTAINABILITY? A MODEL TO ANALYSE HOW ENVIRONMENTAL FACTORS INTERNALIZED IN SUPPLY CHAIN MANAGEMENT**

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## **ABSTRACT**

The purpose of this paper is to formulate a testable comprehensive model of green purchasing approaches. This model is based on literature results and conceptualization. This model was built to provide a testable framework to analyse the real developments in purchasing practice and to describe purchasing management attitude, it was also a purpose to explain the differences of applied green purchasing approaches.

## **INTRODUCTION**

Green purchasing management is emerging to be an important approach in literature. Since the 1990s growing number of articles were published emphasizing the benefits of green supply management to the society, to the supply chain and to the individual company (Bowen et al, 2006). While growing attention of scientific literature focuses environmental issues in purchasing and supply chain management, the number of extensive practical applications is relatively low. There is evidently a gap between the desirability of green supply management and the slow implementation in business practice. This paper intends to address this issue.

The structure of the paper will be as follows. First the literature in the area of green purchasing will be reviewed. As part of concept development it processes scientific papers aiming to structure the means of green purchasing management. It tries to identify models to describe the practical meaning of green purchasing and it aims to synthesize explanations of differences of green purchasing practice. The results of the literature review will be presented in a model.

These results were developed as part of a larger research project. The model described in this paper will be tested in a later phase of the project with the help of a survey.

## **LITERATURE REVIEW - METHODOLOGY**

There is a growing literature of green purchasing and a large number of articles has been published in the recognized scientific journals which is a wealthy source of knowledge and provides a good opportunity to identify gaps in existing research. The questions which needed to be answered were:

- What is the practical content of green purchasing?
- How it is possible to explain the differences between company practices?

However it was a real challenge to find relevant sources, as when we used the keyword "green purchasing practice" or "green supply practice" a lot of irrelevant publications were listed (e.g. consumer behaviour, or sustainable water management). We completed search through databases of Econlit, EBSCO, Springerlink. To delimit the number of publications we used the published literature from 1995 onwards and as the published literature is interlinked, we relied on cross referencing. As we started to integrate the results it was realized that the above mentioned questions are often interrelated: the understanding of green purchasing practice provided an explanation to the differences of usage.

## **LITERATURE REVIEW – THE RESULTS**

Literature of green purchasing is rich in publications offering methodologies of supplier selection (e.g. Awasthi et al, 2010, Bai, Sarkis, 2010, Enarsson, 1998, Handfield et al 2002), investigating the advantages of highlighting green issues in purchasing (e.g. Zhu and Sarkis, 2004, Zhu et al 2008, Rao, Holt 2005) and drawing the motivational background (e.g. Walker et al, 2008, Vorosmarty et al 2011). These results provide a



bright picture of green purchasing practice: it is beneficial, tools are offered. However studies examining motivational issues and green practice show a mixed picture. (e.g. Tate et al 2012, Zhu et al 2005, Zhu et al 2005) This controversy is seldom addressed explicitly in literature (e.g. Bowen et al, 2005). Some explanations might be generated on motivational basis. To gain a deeper understanding it is worth considering those literature results which provide a structured approach to green purchasing.

In an early classification of green purchasing strategies Min and Galle (1997) highlighted the role of green purchasing in source reduction (Recycling, reuse, Sources changes and control) and waste elimination. Carter et al (1998) used a similar definition of environmental purchasing: it consists of purchasing's involvement in activities that included reduction, reuse and recycling of materials. These classifications were tested in both case by surveying manufacturing companies. It was the authors assumption (Craig et al 1998) that there was a reasonably high level of environmental purchasing in the group of consumer products manufacturers. As the green purchasing definitions of these studies are product and material focused it was logical to consider the relevancy of green purchasing mainly for manufacturer.

Green purchasing is often considered as part of green supply chain management, which may be understood as the extension of the previous manufacturing and material focused approach. In SCM context new aspects of strategic coordination are getting recognition such as internal and supplier relationships. Solér et al (2010) results indicate that environmental information is perceived and used differently by purchasers in the supply chain depending on where (in the supply chain) they are situated in relation to other chain actors. Vachon, Klassen (2005) define two sets of green supply chain practice as environmental monitoring (involving activities using markets of arm's-length transactions conducted by the buying organization in order to evaluate and control its suppliers) and environmental collaboration (activities comprising a direct involvement of the buying organization with its suppliers to jointly develop environmental solutions). This classification also considers the segmentation of the supply base and the supply strategy. The idea of supplier segmentation in green purchasing context is elaborated in the theoretic paper of Krause et al (2009). They reveal that the portfolio segments (in case of the Kraljic matrix) can not be equally treated: not just sourcing strategy, but green management practice should be chosen according to the characteristics of the segments. So e.g. the importance of the sourced item, the buyers position influence the applicable green purchasing tools and the potential benefits.

Recent literature deals with defining applicable sourcing strategies. Hamner (2006) identifies 5 basic types of strategy used by companies for green purchasing: vendor questionnaires, use of environmental systems, life-cycle assessment, product stewardship, collaboration and relationships. Bowen et al (2006) developed a categorization of green purchasing strategies based on a survey: product-based green supply (collaboration with suppliers to eliminate packaging, recycling and waste reduction), greening the supply process (e.g. building environmental criteria into the vendor assessment process) and advanced green supply.

## **RESEACH FRAMEWORK OF GREEN PURCHASING PRACTICE**

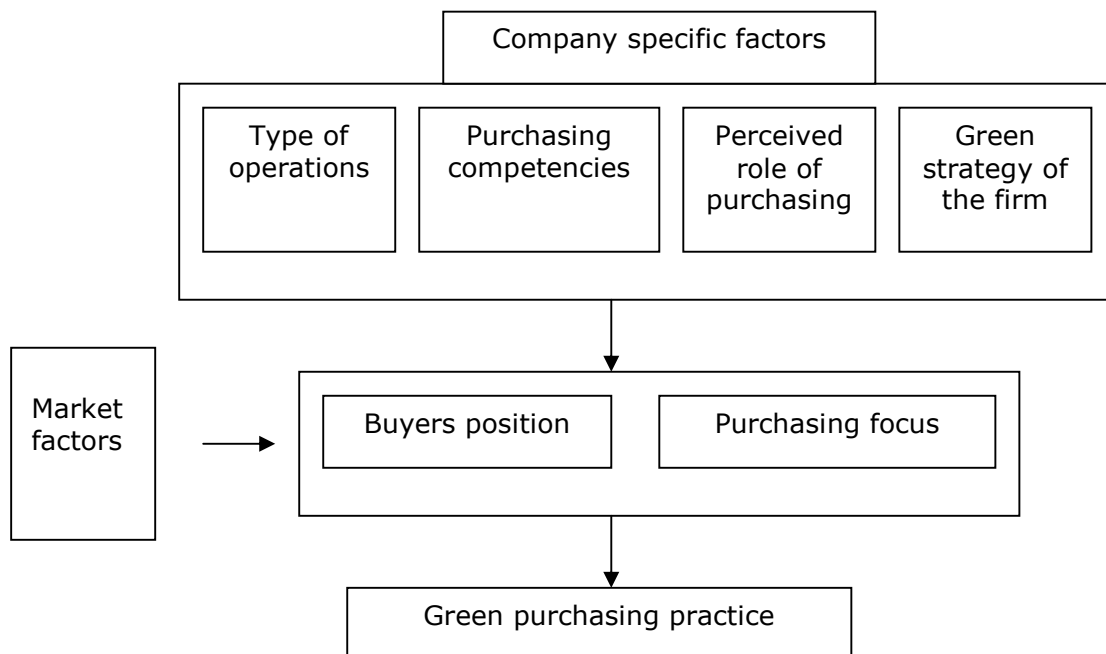
The brief review of literature revealed that there are **company specific (internal) factors** of green purchasing practice. First the **type of company activities** influences the green purchasing practice: high importance of materials (e.g. high spend of manufacturing companies) or company size promote not just the importance of greening purchasing but the possibility of using green purchasing tools). **Advanced purchasing competences** form the basis of supply strategy e.g. portfolio management, appropriate supplier selection, supplier management. It also promotes the knowledge of green purchasing tools. The **perceived role of the purchasing** function within the organisation helps internal collaboration. Purchasing practice should be aligned with **company practice**, it is assumed that e.g. the company's green policy is limited to compliance to legal regulations, than it is not likely that purchasing use highly sophisticated green tools.

**Market factors** are diverse, among which the characteristics of the supply base is important. (Our hypothesis is that the suppliers relative position, the suppliers willingness for collaboration and green purchasing practice of supplier are the major factors.)

Market factors and company specific factors provide the framework that defines the buyers position (what means can be used in the given situation) and the purchasing's potential focus (what is worth using).

This context rationalise the differences of green purchasing practice. Company specific factors and market factors justify differences among companies and it pinpoints category management differences as well. It is a methodological challenge to handle this twofold distinction in a survey, which is not yet addressed in literature. The described model will be further elaborated (setting stages of green purchasing practice considering active and passive tools and forming hypotheses how the stages influenced by the factors of our model) and tested with the help of a questionnaire.

Figure 1.



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# COGNITION MAP OF ENVIRONMENTALLY-ORIENTED GOVERNMENT PROCUREMENT: AN APPLICATION OF THE DEMATEL APPROACH

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## ABSTRACT:

**Purpose:** The objective of this study is to identify the critical determinants of environmentally-oriented government procurement in Singapore and investigates the causal relationships among the determinants influencing environmentally-oriented procurement.

**Design/Methodology/Approach:** A three-part questionnaire was employed for interviews and data collection. A total of sixteen interviews were conducted with senior officials working in various Ministries and Statutory Boards in Singapore. They were chosen based on the consideration that they play critical role in decision-making in government procurement process and have extensive experience in procurement. The DEMATEL cognition mapping process was used to analyse data and determine the determinants influencing environmentally-oriented procurement.

**Findings:** The results show that government statutory boards and ministries in Singapore engaged in environmentally-oriented procurement should pay attention to the determinants such as organisations' commitment, ISO 14001, and energy efficiency.

**Originality/Value** - This study not only identified the critical determinants environmentally-oriented public procurement but also developed the casual relationships between these determinants. An assessment of the direct and indirect impacts through the casual relationships between drivers and receivers would help mangers develop appropriate strategies for the implementation of environmentally-oriented government procurement in Singapore.

**Practical Implications** - Understanding of the dynamic nature of the government procurement through these causal relationships is critical to the formulation of environmentally-oriented procurement implementation strategies.

**Keywords:** DEMATEL approach; Determinants; Environmentally-oriented procurement; Singapore.

## 1.0 INTRODUCTION

The government, as the single largest buyer of goods and services in any economy, has the capacity to influence the demand for more environmental products (Li & Geiser 2005). Government procurement therefore has been identified as one of the policy instruments to achieve environmental sustainability (Crosby & Cameron, 2008). Review of the literature suggests that research on environmental practices in business organisations is a new development and is rapidly gaining importance. Especially in government procurement where there is limited research, although some studies such as Coggburn & Rahm (2005) which looked at the nature of environmental purchasing in the US government or Day (2005) and Walker and Brammer (2009) focused on the role of public authorities to procure sustainable products and services. Studies investigating the critical determinants of government procurement are rare. Hence, this study aims to fill this gap.

The remainder of the paper is organised as follows. Section 2 provides a brief description on public procurement in Singapore and section 3 provides a brief review of literature respectively identifying critical determinants of environmentally-oriented procurement practices. Section 4 provides the methodology to analyse data. Findings of

the study and discussion are presented in Section 5. Finally, section 6 presents the conclusion of this research.

## 2.0 PUBLIC PROCUREMENT IN SINGAPORE

Singapore is a city state with an area of more than 700 square km with a total population size of more than 4 million people and the GDP of more than S\$250 billion or US\$182 billion (World Bank, 2010). With more than 120,000 employees, the central system of government is the Civil Service consisting of 15 ministries and subdivided into various departments as well as more than 40 statutory boards to manage and deliver strategic services (Jones, 2002).

It is estimated that the value of Singapore Government procurement is above US\$22 billion annually (Table 1). The bulk of Singapore Government procurement activities is decentralised to individual ministries, departments and statutory boards. Procurement activities undertaken by various ministries, departments and statutory boards adhere to central procurement guidelines issued by the Ministry of Finance (GeBiz, 2008).

**Table 1. Size of Government Procurement**

Countries	Procurement size (US\$) billion	% of GDP
Singapore	22.3	10.7
Malaysia	30.2	12.7
Indonesia	63.0	9.1
USA	250.0	17.3
China	86.0	13.4
Australia	15.7	17.0

Source: World Bank (2010)

## 3.0 LITERATURE REVIEW

An extensive literature review identified ten determinants of environmentally-oriented procurement. A brief discussion of these determinants is provided below:

### 3.1 Energy efficiency

Energy efficiency refers to using less energy to produce the same amount of services or output (Patterson, 1996). It is an essential component in the agreements contained in the Kyoto Protocol to address greenhouse gas (GHG) and carbon emission (Mlecnik et al., 2010, Wu et al., 2010). Energy efficiency is one of the key measures adopted by many governments to address climate change caused by carbon emission. Singapore, for example, is focusing on a 35% improvement of energy efficiency from 2005 levels by 2030 (MEWR and MND, 2009)

### 3.2 Biodegradability

Biodegradability is often associated with environmentally friendly products. A material is defined as biodegradable if all of its organic components are subject to decomposition through biological activity (Industrial Lubrication and Tribology 1992). Biodegradable plastics are considered as one of the options available to manage environmental problems.

### 3.3 Packaging

Almost all goods purchased come with packaging. Packaging contributes to waste and packaging waste includes glass, paper, board, metals and wood. It makes up over half of

our household waste which is growing in volume and weight. It also signifies the growing contribution of packaging in the waste stream (CIWM, 2010). The Packaging Waste Directive promulgated by the European Union in 1994, among other things, aims to eliminate dangerous materials from packaging, reduce the proportion of packaging waste going to landfill; increasing recovery and recycling of packaging waste (CIWM, 2010).

### *3.4 Reverse logistics*

One way of minimising the environmental impact of waste is to use reverse logistics to increase the amount of product materials recovered from the waste stream. Reverse logistics is a process by which a manufacturer systematically accepts previously shipped products or parts from the point of consumption for possible reuse, remanufacturing, recycling, or disposal. Thus reverse logistics has important environmental dimensions (Ciliberti et al., 2008) as well as dimensions relating to value reclamation (Ilgin and Gupta, 2010).

### *3.5 ISO 14001*

ISO 14001 is about environmental policy statement that require commitment to continually improve and prevent pollution, to comply with legislations and regulations, a framework for setting and reviewing environmental goal. Studies show that ISO 14001 often leads to reduce environmental impact especially waste reduction.

### *3.6 Product design*

Product design is an environmental management strategy that means whoever designs, produces, sells or uses a product takes responsibility for minimizing the products environmental impact through all stages of the products lifecycle (Toffel 2002). It is argued that the amount of waste generated is a direct consequence of decisions made during product design (Bowman 1996; Melynk et al., 1996).

### *3.7 Life cycle analysis*

IEMA (2005) considers life cycle analysis as a system approach that looks on an overall view of the impacts of products and services used in the economy where products and services used by consumers have their upstream and downstream environmental impacts.

### *3.8 Environmental Entrepreneurship*

Starik and Rands (1995) viewed environmental entrepreneurship as activities revolving around environmental management are considered as priority with the aim to achieve ecological sustainability. Keogh and Polonsky (1998) categorised three types of individual in relation to environmental entrepreneurs in procurement centres - policy entrepreneurs, converts and resisters. The presence of policy entrepreneurs and converters shapes the orientation of organisation to focus on environment.

### *3.9 Commitment*

Commitment leads to successful inter-organisational integration and serves to reinforce the commitment between partners sharing mutual goals and values that enable them to that enable them to trust and work closely to achieve better coordination to fulfil mutual goals (Handfield & Bechtel, 2002).

### *3.10 Innovation*

Research by Edler et al. (2005) on nine cases of public procurement in several European countries showed innovation in public procurement corresponds to market development.

**Table 2. Determinants of Environmentally-Oriented Procurement**

Dimension	Determinant	Source
Integrated Product Attributes	<ul style="list-style-type: none"> <li>Energy Efficiency</li> <li>Biodegradability</li> </ul>	Mlecnik et al. (2010); Wu et al. (2010); MEWR and MND (2009); Zheng, Yanful and Bassi (2005).
Waste Management	<ul style="list-style-type: none"> <li>Reverse Logistics</li> <li>Packaging</li> </ul>	Ciliberti et al (2008); Mollenkopf et al. (2005); Davis and Song (2005).
Organisation Systems, Processes and Policies	<ul style="list-style-type: none"> <li>ISO14001</li> <li>Product Design</li> <li>Life Cycle Analysis</li> </ul>	EITayeb, Suhaiza and Jayaraman (2010); Lee, (2005).
Organisational Values	<ul style="list-style-type: none"> <li>Entrepreneurship</li> <li>Commitment</li> <li>Innovation</li> </ul>	Elder et al. (2003); Keogh and Polonsky (1998); Hendrickson & Tuttle (1997).

#### 4. RESEARCH METHODOLOGY

##### 4.1 Method

The Decision-Making Trial and Evaluation Laboratory (DEMATEL), originated at the Battelle Memorial Institute, Geneva between 1972 and 1976. It is an effective procedure for analyzing problem structure and develop causal relationships between factors or sub-systems (Fontela and Gabus, 1974). The DEMATEL methodology has been applied in many fields, such as in decision making and product design (Lin, Wang and Tseng, 2009). The procedural steps of DEMATEL methodology are as follows:

Step 1: *Generate direct-relation matrix*: Suppose there are  $R$  decision-makers (experts) involved in the study and  $n$  number of decision-making factors. Each decision-maker  $k$  is asked to indicate the degree to which a factor  $i$  affects factor  $j$ . These pairwise comparisons between any two factors can be denoted by  $x_{ij}^k$  and given an integer score ranging from 0, 1, 2, 3, and 4, representing 'No influence', 'Low influence', 'Medium influence', 'High influence', and 'Very high influence' respectively. The elements for  $i = j$  are set to zero. Responses from each decision-maker give rise to a  $n \times n$  non-negative matrix,  $[x_{ij}^k] = X^k$ , where  $k =$  number of decision-makers varying between 1 and  $R$ . An initial direct-relation matrix  $A$  with individual element  $a_{ij}$ , can therefore can be expressed as;

$$[a_{ij}]_{n \times n} = \frac{1}{R} \sum_{k=1}^R x_{ij}^k \quad (\text{equation 1})$$

Step 2: *Normalizing the direct-relation matrix*: The normalized direct-relation matrix  $M$  can be obtained by the following expression:

$$M = \frac{A}{\mu} \quad \mu = \max(\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}, \max_{1 \leq j \leq n} \sum_{i=1}^n a_{ij}) \quad (\text{equation 2})$$

$\mu$  ; where

Step 3: *Obtaining the total-relation matrix*: Once the normalized direct-relation matrix is obtained, the total relations matrix  $T$  can be derived from the following expression:

$$T = M + M^2 + M^3 + \dots + M^\infty = \sum_{i=1}^{\infty} M^i$$

$T = M(I - M)^{-1}$ , where  $I$  is an identity matrix (equation 3)

*Step 4: Compute dispatcher group and receiver group:* Define  $S$  and  $C$  as  $n \times 1$  and  $1 \times n$  vectors representing the sum of rows and sum of columns of the total-relation matrix  $T$ , respectively. Suppose  $S_i$  be the sum of  $i$ th row in matrix  $T$ , then  $S_i$  summarizes both direct and indirect effects given by factor  $i$  to the other factors. Similarly, suppose  $C_j$  be the sum of  $j$ th column in matrix  $T$ , then  $C_j$  summarizes both direct and indirect effects given by factor  $j$  to the other factors. The expression  $(S_i + C_j)$  indicates the degree of importance that factor  $i$  plays in the entire system, whereas,  $(S_i - C_j)$  indicates the net effect that factor  $i$  contributes to the system. If  $(S_i - C_j)$  is positive, factor  $i$  is net dispatcher, and if  $(S_i - C_j)$  is negative, factor  $i$  is a net receiver.

*Step 5: Set threshold value and obtain the cognition map:* The cognition map can be derived by mapping the dataset of the  $(S_i + C_j)$  and  $(S_i - C_j)$ , where  $(S_i + C_j)$  is the horizontal axis and  $(S_i - C_j)$  is the vertical axis. To construct an appropriate map, a decision-maker must assign a threshold value for the influence level. Only some factors whose influence level in matrix  $T$  is higher than the threshold value will be chosen to construct the map. If the threshold value is too low, the map will be too complicated, whereas, if the threshold value is too high, many factors will remain independent without showing the relationships with other factors.

#### 4.2 Sampling and data collection

A three-part questionnaire was employed for interviews and data collection. Part 1 contained general questions about the company and respondents' background, whereas, Part 2 contained ten open-ended questions designed to capture respondents' opinions on the importance of ten determinants regarding environmental orientation of public procurement. Part 3 contained questions regarding generation of direct-relation matrix (Step 1 of the DEMATEL Methodology) using respondents' perception on the influencing power of one determinant over another based on the scale 0-4.

None of the respondents were familiar with the DEMATEL data collection procedure. Therefore, the following two steps were considered:

1. Respondents were explained the meaning of the integer scores of the 0-4 scale.
2. Respondents were explained how these scores need to be considered while making the pairwise comparisons between any two factors.

#### 4.3 Application of the DEMATEL

As discussed in the literature review section, ten determinants were identified for assessing the criticality of the determinants and their relationships. These factors are D1: Energy efficiency, D2: Biodegradability, D3: Packaging, D4: Reverse logistics, D5: ISO standards, D6: Product design, D7: Life cycle analysis, D8: Entrepreneurship, D9: Commitment, and D10: Innovation. A total of sixteen interviews were conducted with senior officials working in various Ministries and Statutory Boards in Singapore. They are directly involved in procurement, logistics and operations. They were chosen based on the consideration that they play critical role in decision-making in government procurement process and have extensive experience in procurement, ranging from five to more than 20 years. In terms of educational qualification, 44 % of the respondents holds a master degree and the other 56 % holds a bachelor degree. These officers understand and value the importance to be environmentally-oriented. Some of them had implemented measures to ensure that environmentally-oriented practices are observed in the organisations. They also know that there is an inter-ministries blueprint on sustainability. The respondents belonged to the category of large organisation and twelve respondents indicated that their organisations have achieved Green Mark or ISO19001 certifications.



**Table 3. Characteristics of Respondents**

No	Organisation	Position	Qualification & work experience in procurement
1	Statutory Board 1	Director	Master degree. 20 years
2	Ministry A	Assistant Director	Master degree. 5 years
3	Statutory Board 2	Deputy Director	Bachelor degree. 10 years
4	Statutory Board 3	Assistant Director	Bachelor degree. 20 years
5	Statutory Board 4	Director	Master degree. 20 years
6	Statutory Board 5	Assistant Director	Bachelor degree. 10 years
7	Ministry B	Senior Manager	Bachelor degree. 10 years
8	Ministry C	Deputy Director	Master degree. 20 years
9	Ministry D	Director	Master degree. 5 year
10	Statutory Board 6	Director	Master degree. 20 years
11	Ministry E	Assistant Director	Master degree. 10 years
12	Statutory Board 7	Director	Bachelor degree. 20 years
13	Ministry F	Assistant Director	Bachelor degree. 5 years
14	Statutory Board 8	Assistant Director	Bachelor degree. 10 years
15	Statutory Board 9	Deputy Director	Bachelor degree. 20 years
16	Ministry G	Assistant Director	Bachelor degree. 10 years

**Table 4. Characteristics of Organisations**

No	Organisation	No of employees	Certification
1	Statutory Board 1	500 - 999	Green Mark
2	Ministry A	> 1000	ISO9001
3	Statutory Board 2	100 - 199	None
4	Statutory Board 3	10 - 49	ISO9001
5	Statutory Board 4	200 - 499	Green Mark
6	Statutory Board 5	200 - 499	None
7	Ministry B	> 1000	None
8	Ministry C	500 - 999	ISO9001
9	Ministry D	> 1000	None
10	Statutory Board 6	> 1000	Green Mark
11	Ministry E	> 1000	ISO9001
12	Statutory Board 7	500 - 999	ISO9001
13	Ministry F	500 - 999	ISO9001
14	Statutory Board 8	200-499	ISO9001
15	Statutory Board 9	> 1000	ISO9001
16	Ministry G	> 1000	ISO9001

## 5. RESULTS AND DISCUSSION

Considering sixteen responses from senior officials of various organisations in Singapore, sixteen matrices were generated using pairwise comparison. These were then used to obtain an average matrix using equation 1 (see section 3). By using equation 2 a normalized direct-relation matrix was generated. Finally, the total relation-matrix was computed using equation 3, which is shown in Table 5. The direct and indirect influence of recycling operations implementation factors are shown in Table 6.

**Table 5. The total-relation matrix.**

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
D1	0.292	0.363	0.412	0.401	0.431	0.456	0.209	0.408	0.433	0.451
D2	0.321	0.219	0.374	0.334	0.358	0.369	0.217	0.328	0.353	0.366
D3	0.333	0.312	0.291	0.378	0.394	0.413	0.203	0.384	0.409	0.394
D4	0.292	0.277	0.342	0.227	0.308	0.336	0.213	0.299	0.225	0.332
D5	0.347	0.321	0.375	0.358	0.302	0.416	0.307	0.387	0.415	0.415
D6	0.332	0.291	0.379	0.346	0.362	0.292	0.212	0.363	0.388	0.394
D7	0.345	0.31	0.364	0.348	0.373	0.374	-0.087	0.365	0.387	0.404
D8	0.309	0.274	0.335	0.299	0.359	0.351	0.256	0.248	0.375	0.389
D9	0.355	0.296	0.352	0.331	0.398	0.37	0.224	0.348	0.303	0.431
D10	0.321	0.273	0.325	0.297	0.345	0.357	-0.023	0.333	0.369	0.274

**Table 6. Degree of influence of the determinants**

	S	C	S + C	S - C
D1	3.856	3.247	7.103	0.609
D2	3.239	3.226	6.175	0.013
D3	3.511	3.549	7.060	-0.038
D4	2.851	3.319	6.288	-0.350
D5	3.643	3.340	7.273	0.303
D6	3.359	3.734	7.093	-0.375
D7	3.183	1.731	4.914	1.452
D8	3.195	3.463	6.658	-0.268
D9	3.408	3.657	7.757	-0.349
D10	2.871	3.850	6.721	-0.979

The importance of determinants is assessed by  $(S_i + C_i)$  values, as indicated in section 3. The higher the value, the more important the determinant is. Based on  $(S_i + C_i)$  values, the importance of ten determinants can be prioritized as  $D9 > D5 > D1 > D6 > D3 > D10 > D8 > D4 > D2 > D7$ . The results show that the three most important factors are D9: Commitment (7.757), D5: ISO14001 (7.273) and D1: Energy efficiency. Whether a determinant is net driver or a net receiver depends on  $(S_i - C_i)$  values. If  $(S_i - C_i)$  value is positive, determinant is a net driver, and if  $(S_i - C_i)$  value is negative, determinant is a net receiver. The results indicate that the three most influential drivers are D7: Life cycle analysis (1.452), D1: Energy efficiency and D5: ISO 14001 (0.303).

This study not only identified the critical determinants environmentally-oriented public procurement but also developed the casual relationships between these determinants. Following the procedure suggested by Tamura et al. (2002), a threshold value of 0.410, which is more than the average of the elements of matrix T (equation 3), was considered to construct the relationship map (Figure 1). The map has been constructed using  $(S_i + C_i)$  as the X-axis and  $(S_i - C_i)$  as the Y-axis.

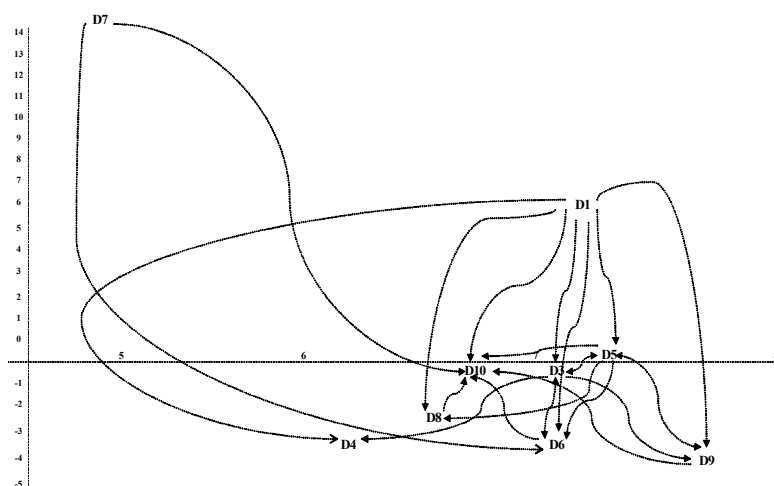


Figure 1. The relationship map

The relationship map, shown in Figure 1, indicates that among the drivers, D7: Life cycle analysis is the main determinant. D7 directly impacts on D10: Innovation and D6: Product design. The determinant D1: Energy efficiency directly impacts on seven other determinants such as D3, D4, D5, D6, D8, D9 and D10. Also both D5 and D9 impacts on D10. Understanding of the dynamic nature of the government procurement through these causal relationships is critical to the formulation of environmentally-oriented procurement implementation strategies.

## 6. CONCLUSIONS

This study proposed a framework to implement environmentally-oriented government procurement using ten determinants. These determinants are energy efficiency; biodegradability; packaging; reverse logistics; ISO 14001; product design; life cycle analysis; entrepreneurship; commitment and innovation. The results show that government statutory boards and ministries engaged in environmentally-oriented procurement should pay attention to the important determinants such as organisations'

commitment, ISO 14001, and energy efficiency. Also, they must give special consideration to the determinants categorized as drivers (energy efficiency, life cycle analysis, ISO 14001, and packaging). An assessment of the direct and indirect impacts through the casual relationships between drivers and receivers would help managers develop appropriate strategies for the implementation of environmentally-oriented government procurement in Singapore.

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# SUSTAINABILITY AND THE PURCHASING PROCESS FOR PHYSICAL DISTRIBUTION SERVICES

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## ABSTRACT

Sustainability in physical distribution has been widely discussed, but academic research has concentrated on how to achieve sustainability and on techniques and measures to improve sustainability. But our understanding of the role played by sustainability during the purchasing process is limited. This is a pity. If sustainability is more as mere words, it needs to find a proper place in KPI's in the service level agreement for physical distribution services. In this way it could be the enabler, for both shipper and logistics service provider, to improve a common understanding of what sustainability means and how it can be achieved. This research paper will define this role and describe the problems which shippers and logistics service providers face when improving the sustainability of physical distribution. It also will show the results of a case study amongst 5 companies and will show that the role sustainability plays in the purchasing process is not clearly cut. At the end we will introduce a survey amongst 20,000 shippers and logistics service providers to gain a better understanding of this aspect.

## INTRODUCTION

The logistics sector in the Netherlands is of great economic importance and contributes substantially to the Dutch economy. The added value of logistics for 2010 to the Dutch GDP is estimated at € 40 billion (8.5%), and its contribution to employment is approximately 750,000 jobs (10%). These figures relate to logistics service providing only. The function of logistics in industry, wholesale, health care, etcetera, should be added to that. For several years, sustainability features on top of the agendas of logistics service providers (Ploos van Amstel, 2008). That fits in the general pattern of environmental awareness of all players in logistics - industrial companies, retail, wholesale, transport and authorities alike, all taking initiatives to incorporate sustainability into their operating strategies (De Ron, 2001; McDonough & Braungart, 2002). This is not just a typical Dutch issue. The EU also wants freight transport to be cleaner (European Commission, 2004; European Commission, 2011). It is expected that sustainability will become one of the prime drivers within the supply chain (Van den Broek & Van den Broek-Serlé, 2010).

But how do both logistics service providers and principals/shippers succeed in making one aspect of the supply chain, physical distribution (Ploos van Amstel, 2008) more sustainable? What lessons can be learned from those logistics service providers and shippers who are *best in class*? And what can be learned from the way all involved parties deal with sustainability issues in the purchasing process for transportation? After all, if sustainability is not an aspect within the purchasing process for transportation, is sustainability really an important issue for all parties involved or just political correct empty phrases, full of sound and fury. Signifying nothing.

We want to get at results, not just the promised and fine speeches, by investigating the role of sustainability during the various phases of the purchasing process (Van Weele, 2009) of physical distribution services. Does sustainability play a part in all phases of procurement, or is it being ignored in some phases? For reducing CO<sub>2</sub>, is there a difference between shippers compared to logistics service providers?

With most literature on sustainable transportation concentrating on techniques of how to improve sustainability (e.g. the articles in the International Journal of Sustainable

Transportation), it is surprising to see that the relationship between shippers and logistics service providers hardly is researched. Andersson and Norrman (2002) are an exception and they do not even mention sustainability! De Haan, Naus and Overboom (2011) describe KPI's to be put in the service level agreements, but do not mention sustainability as one of these KPI's. Kudla and Klaas-Wissing (2012) have made case studies on the role of sustainability in the relationship between shippers and service providers but they don't mention service level agreements. Our study on sustainability and its place in the service level agreement will help to increase our understanding on how to make physical distribution more sustainable.

The main question we will answer is:

To what extent and how do logistics service providers and shippers translate their strategic policy in the field of sustainable physical distribution into activities during the purchasing process of transportation services?

First of all, answering this question requires further investigation into the relationship between what is said and what is done. When a shipper opts for outsourcing physical distribution, the relationship between a logistics service provider and his shipper will be reflected in the juridical contract drawn up to facilitate and clarify future transport orders between the two partners. Such a contract will be made up in the form of a service level agreement, that informs all parties concerned about mutual expectations and what rules do apply (Faber et al., 2009). In order to control the performance, key performance indicators (KPI) will have to be defined, as well as procedures for the calculation and the evaluation of these KPIs (Bask, 2001). A typical service level agreement would take the form of a call-off contract, within a framework for future individual transport orders. Every individual order should have to fit in the agreed call-off contract. The call-off contracts have to reflect the appreciation of all parties concerned for specific KPI like price, reliability etc. including sustainability. If the call-off contracts represent the view of the companies concerned, sustainability could be considered a top aspect, which decides the choice for a particular logistics service provider. When is opted for insourcing physical distribution what demands are made on the private carrier as far as sustainability aspects are concerned?

This particular research is part of a PhD study in the role of sustainability within physical distribution with the emphasis on determining the drivers, barriers and enablers for the various stakeholders involved in this process.

The conceptual framework for our research is based on the same heuristic model used in the 1994 NEA/Cranfield study. Weijers, Kuipers and Becker (2002) adapted this framework for research in industry driven innovations for logistics service providers. We have adapted their model to trace the elements in sustainable physical distribution trends.



Figure 1 Conceptual Framework

In our conceptual framework we assume that every shipper and logistics service provider operates within his own specific environment (financial situation, market, customers and location) and has his own special mix of forces for change (drivers, enablers and barriers). Combining these elements, the logistics service provider or the shipper could develop a plan for achieving a higher level of sustainability. This strategy could be written down explicitly or implicitly embedded into the company's mission. Based on this strategy the logistics service provider or shipper implements the plan or maintains the status quo.

Using this conceptual framework we want to understand if new types of physical distribution networks or new approaches for transportation have been developed due to a change in the company's strategy for sustainability. This change in strategy may (or may not) be influenced by the forces for change as explained above. We expect these new types of physical distribution networks or new approaches will result in new demands on physical distribution systems and, this will drive innovations in sustainable physical distribution.

Based on this conceptual model our argument proceeds as follows: First, we present our defense of the concept for "sustainable" physical distribution. Next we introduce the place sustainability has in the demand and in the purchasing process for physical distribution services. We have taken 5 companies as case studies (Yin, 2009) in order to determine our definite hypothesis which will be tested in a survey amongst the members of a national organization which represents the logistics interests of 20,000 companies, producers and traders in the Netherlands. This group will provide us with a good cross section of small, medium and large logistics service providers and shippers and will allow us to get a strong impression of our target group's views.

### **SUSTAINABLE PHYSICAL DISTRIBUTION**

In 2008, transportation was responsible for 21% of all CO<sub>2</sub> production within the Netherlands—road transport (private and freight) comprises the largest portion at 7%. The remainder is divided into inland shipping (5%), rail (0.3%), air transportation (1.8%) and sea transport (14%). Within road transport, freight transport comprises 36% (Van der Meulen and Kindt, 2010). These figures show that the Dutch freight transport sector produced a considerable amount of CO<sub>2</sub> (6%) in the Netherlands in 2008. In the near future, the Dutch logistics service providers and shippers will need to control or, even lower the amounts of CO<sub>2</sub> produced (European Commission, 2004; European Commission, 2011; Topteam Logistiek, 2011).

What makes freight transportation services sustainable is not altogether clear, therefore it follows that what makes a logistics service provider more sustainable is not clear cut. This could be due to a lack of a generally accepted definition of sustainable transportation (Pezzey, 1997). The definition provided by the Brundtland Commission (World Commission on Environment and Development, 1987) is often used as a standard definition (Jeon & Amekudzi, 2005), but this is difficult to translate into hard, measurable facts. As most trucks still employ an implosion engine, it can be stated that every litre of gasoline used for transportation today will not be available for future generations. The Brundtland based definitions therefore fail to be realistic and usable. A definition of Environmentally Sustainable Transportation (EST) as developed by the OECD is more precise and will serve as the basis for our research:

*Transportation that does not endanger public health or ecosystems and meets the needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes (OECD 1999).*

This definition takes three aspects of EST into account: public health, ecosystems and natural resources. As a framework for environmental indicators, the Pressure-State-Response (PSR) model was developed by the OECD (1993). PSR provides a mechanism to monitor the status of the environment. The PSR cycle also provides a framework for investigation and analysis of processes involved in environmental degradation. In addition to application at national, regional, local and other sub-national levels, it can also be used for a sectoral analysis, and adapted to individual projects.

The idea behind the PSR model is that human activities exert pressures on the environment that affect its quality and the quantity of natural resources (state). Society then responds to these changes through environmental, general economic and sectoral policies, and through changes in awareness and behavior or activities (societal response). The PSR model takes the pressures and the driving forces behind these activities into consideration and not the symptoms resulting from a changed state itself.

When discussing sustainable transportation, the attention focuses on reducing exhaust gases. The main exhaust gases are carbon dioxide (CO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM) (Francke et al., 2009). There are more polluting exhaust gases concerning transportation like carbon monoxide (CO) and hydrocarbons (HC) (Van der Meulen & Kindt, 2010), but these two gases were never mentioned on the researched websites or by the survey respondents. In short, almost the literature on sustainable freight transportation, (Dutch) government information available on this subject, and from the researched target groups, concentrates on CO<sub>2</sub> reduction. The other gases are hardly mentioned. As for the transport sector itself, just two logistics service providers mentioned the four main gases, but do not show how they are trying to reduce them. Our research has followed this lead and also concentrates on the reduction of CO<sub>2</sub>.

**SHIPPERS VERSUS LOGISTICS SERVICE PROVIDERS**

The shipper as a customer of the logistics service provider plays an important role. The transport market is best described as being dominated by heavy competition and low profit margins, so the customer is certainly king (Christopher 2005). But how important is sustainability for these customers of logistics service providers? A survey amongst shippers conducted by Van der Meulen and Kindt (2010) found that shippers used certain criteria when selecting a logistics service provider. The criteria included: reliability, price, service, sustainability and innovation. When asked to rank these criteria, the results favored price and reliability, with sustainability near the bottom, in fourth place.

**Table 1.** Main selection criteria according to shippers

Selection Criteria	Weight Price =100
Price	100
Reliability	94
Service	72
Sustainability	45
Innovation	33

These findings are further supported by literature regarding logistical considerations; choices made in regards to transportation, are usually determined by two things (Christopher 2005; Visser 2010):

1. effectiveness i.e. speed and reliability
2. efficiency (low cost)

In 2010 we conducted a web survey amongst 82 logistics services providers who are connected to HAN University through work placements schemes, etc. We asked them to answer questions about their experience with sustainability. Sixty-one participants accepted this invitation and, of these, 41 completed the survey. The non-respondents gave work pressure and lack of time as reasons for not completing the questionnaire. As





Theoretically all involved with physical distribution should be inspired by the same call-off contract, but what if the operational employees on one or both sides are driven (or measured) by aspects more in line with the findings in Table 1? A problem could result from within physical distribution because the KPIs of service level agreements are often not monitored (De Haan et al., 2011).

If we observe:

- national and local governments impose different restrictions on unsustainable transportation;
- shippers want to get it all: low prices and high service (Christopher, 2005);
- shippers place sustainability below price and service (Van der Meulen & Kindt, 2010)
- customers demand a higher level of socially responsible behavior from the supply chain partners (Maloni & Brown, 2006)
- every shipper chooses a logistics service provider for different reasons (Kraljic, 1983).

We can then conclude that not only do we find a huge array of stakeholders involved in physical distribution, they also place different demands on the logistics service provider. Sustainability is not ranked first, rather the main focus is on price and reliability. However, we see a trend that suggests customers expect value chain partners to behave in a socially responsible way and this includes sustainability.

If we further consider that:

- stakeholders themselves are on different levels, therefore, differing views of sustainable transport could exist;
- a logistics service provider has many different shippers for customers.

The problems become even more complicated. Can a unique solution be found which satisfies each and every stakeholder? In this case, we must conclude that sustainability is surely a wicked problem (Rittel & Webber, 2012; Levin et al., 2012).

## **OUR RESEARCH**

First, we wanted to make sure if sustainability did play a part in the purchasing process and what that role might be. Therefore we selected for a case study (Yin, 2009) five companies (A, B, C, D and E), which will give us a good insight into the various aspects of sustainability and the purchasing/buying process.

Three are food producing companies (A, B and C) who have outsourced transportation, one (D) is a wholesaler/distributor of food items (fresh, frozen and canned) who has insourced physical distribution and the last is a logistics service provider (E) who is very active in promoting sustainability.

Two (C and D) are subsidiary companies of foreign mother companies, the other three (A, B and E) are Dutch owned. They employ between 700 and 2200 full time employees. We conducted an open structured interview of one hour with six persons whose function varied between logistic manager (A, B, D), manager sustainability programs (C), marketing manager (E) and CEO (A). When asked how did they perceive their own company's experience with sustainable physical distribution they ranked themselves from beginner (A, D) to advanced (B and E) and even very advanced (C).

Some aspects were clear from all six interviewees: the main focus for sustainability was to lower costs. We obtained also interesting information on the role of sustainability during the purchasing process. A and B mentioned that they did not include any references to sustainability in the service level agreement at all. It was an aspect to be considered when selecting logistics service providers, but the price determined the final choice. For company C, sustainability was a major issue and was integrated into the service level agreements, but not always was the service level agreement kept. D has the will to be more sustainable, but finds it difficult to make customers understand that their demands on delivery time and quantity have to change in order to get an improved, more sustainable service. E has developed a special program which compensates for CO<sub>2</sub> emissions. The price is 2% more compared with the normal service. They did promote this program, but only 2% of all customers with 1,5% of all transport movement have adopted it. E also mentioned that sustainability is not an issue when signing service level

agreements. Beside C, none of the others did or experienced any follow up on sustainability at the end of the contract period.

Based on the information obtained from these interviews we can state that the role played by sustainability during the purchasing process of physical distribution is not clearly cut. The service level agreement, which could serve as an enabler, seldom contains performance indicators linked to sustainability. But we still have not found answers to what could make service level agreements a good tool, or where and how sustainability is an issue during the various phases of the purchasing process.

To get insight into these questions, we are developing a survey which will be conducted (July 2013) amongst the members of the EVO, an organization which represents the logistics interests of 20,000 companies, producers and traders in the Netherlands. This survey will allow us to answer:

- 1) Do companies have a vision on sustainability and is this vision translated in a strategy for physical distribution?
- 2) What role does sustainability play in the purchasing process of physical distribution?

We are confident that the findings of this survey will help to improve our understanding of how shippers and logistics service providers deal with sustainability. With this improved understanding, we will be able to help logistics service providers and shippers to build better and durable distribution networks.

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# TEMPERATURE MANAGEMENT AND QUALITY ASSESSMENT OF CLIMACTERIC FRUITS IN COLD CHAIN

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## ABSTRACT

Perishable foods need strict environmental conditions when they are transported or stored along the way from production to consumption. In food industry, food incidents, recalls, disputes and rejects could be often seen with respect to safety and quality of food. The longer the journey from producer to consumer the higher the risks of perishability and damage in supply chain due to factors like temperature variations, shock during transfer etc. Therefore, cold chain or temperature-controlled supply chain that provides appropriate facilities and efficient methods is essential in order to maintain safety, quality and integrity of food. Refrigeration is one of most widely used method to date to slow bacteria growth which leads to food deterioration. Proper control and management of temperature is essential to deliver perishable food in safe and good quality to the hands of consumers. The purpose of this study is to investigate the viable procedures and methods for temperature management and quality assessment of climacteric fruits in cold chain.

Keywords:

cold chain, temperature management, climacteric fruits, monitoring, quality

## INTRODUCTION

Perishable goods which are time and temperature sensitive in nature are of higher value and more vulnerable to temperature disturbances. Logistics industry needs more attention to handle perishables as they need quick and smart decision than non-perishables. For perishable products, the cold chain remains one of the most important ways to preserve perishables and deliver them to market in safe and good condition. The shelf life, quality and safety of perishable foods throughout the supply chain is greatly impacted by environmental factors especially temperature. Not only economic loss due to wastage but also safety, quality and security of the food are big concerns faced by food industry today. Temperature abuse in the cold chain can cause microbial growth and spoilage of the food product, thus becoming the factor for causing food-borne illness. The threat of bioterrorism also enforces all actors to establish and maintain records to enhance the security of the cold chain. Managing cold chain not only keeps products at the right temperatures, but also increase supply chain efficiency and reduce costs.

Cold Chain Management (CCM) deals with efficient control and organization of production and logistics regarding temperature. It comprises of planning and implementation of single processes and process steps as well as implementation of instruments and methods of process monitoring and control. The principal aims of CCM are the optimization of product quality, product safety and minimization of wastage. In practice, CCM often means temperature monitoring at each step within the production, storage and transportation chain on inner- and inter-operation levels. Nowadays wireless intelligent solutions can monitor the cold chain and reduce risks in transit—by land, sea, and air. For temperature monitoring, the use of Time-Temperature-Indications (TTI) and Radio Frequency Identification (RFID) systems altogether with Wireless Sensor Network (WSN) has become essential.

## **LITERATURE REVIEW**

Previous research is investigated to know the recent trend of cold chain applications. SARDI (2006) and Carullo et al. (2008) suggested that perishable foods must be continuously monitored for safety and quality concerns throughout the whole supply chain. However, commercial systems that are presently available for monitoring containers, refrigerated chambers and trucks do not give complete information about the cargo, because they typically measure only a single or very limited number of points (Mitsugi et al., 2007). Wireless sensor network provides a flexible and powerful solution to monitor and control a cold chain at different levels of the logistical chain. Qingshan et al. (2004) considered that refrigerated vehicles can be a crucial point as products may undergo transient conditions during transport and distribution process. Ruiz-Garcia et al. (2007) analysed a monitoring of intermodal refrigerated fruit transport that integrate wireless sensor networks with fleet management systems and mobile networks. More intelligence could be achieved by combining WSNs with other technologies such as RFID and agents (Jedermann et al., 2006; Behrens et al., 2006). Sensors are not only placed in refrigerated room or container but also attached to the products itself (for e.g. wine or milk bottles etc.) using specially designed sensor nodes to detect environmental conditions and to determine the actual quality levels of individual products more accurately (Sashin et al., 2007; Carullo et al., 2008; Mattoli et al., 2010). Also sensors applications are found in combination with other systems. Abad et al. (2009) demonstrated a real-time traceability and cold chain monitoring system for foods by using smart RFID tag in intercontinental fresh fish logistic chain. Wang et al. (2010) presented a real-time monitoring and decision support system, with the combination of existing technologies such as RFID, WSN, GPS and rule-based decisions to improve the delivery system for perishable products.

In summary, the previous research highlight that transportation is the most focused area in cold chain. Different application-specific sensors are designed to use for complex food supply chain since it has many diverse process and products. Integration with other technologies is desirable to achieve performance and intelligence of the system as well. Web-based system is a promising trend of cold chain system today to trace back the quality and safety of food. However, the previous researches mainly focused on monitoring and performance issues of wireless sensor network in food industry rather than assessment to quality of products impacted by temperature.

### **A DESCRIPTION OF THE PROBLEM OR CHALLENGE**

Cold chain typically focuses on temperature control and management in order to prevent the growth of micro-organisms and deterioration of products during processing, storage, and distribution. It includes all segments in the food supply chain from the producer to the consumer. Therefore, it can be seen as a single entity since a breakdown in temperature control at any stage can impact the final quality of the product (Miles et al., 2008). The supply chain can be quite complex when dealing with food products. The limited lifetime and the deteriorating quality of perishable foods over time contribute substantially to the complexity of their management (Bowman et al., 2009). In food industry, deterioration arises mainly on fresh products, because of its short shelf life and perishability (Xiaohung et al., 2010).

A recent study shows temperature-controlled shipments from supplier to distribution centre/store encounter the situation where the temperature rises or falls from the specified temperature account from 15% to 36% of trips (White, 2007). The optimization of temperature control in storage facilities such as refrigerated truck, warehouse and cold store is crucial in today's operation of cold chain logistics. Temperature management is very complex in the situation where mixed loading of perishables is often required. The biggest challenge is the diverse characteristics of perishable foods that demand different temperature requirements.

Unlike other products, fresh products have tough temperature requirement during their logistics processes. Temperature requirements vary among food items, whether frozen or chilled and they even differ across types of foods. Even short exposures like a few hours to extreme hot or cold temperatures can cause a marked decrease in shelf life and loss of quality. Correct and careful temperature management throughout the supply chain is essential if quality of the product is to be assured (Jobling, 2000). The more distant the real storage temperature of a product is of its ideal temperature, the greater the costs with the loss of quality of this product. It was verified that the cost relating to the loss of quality of products has great influence on the total storage cost (Borghini et al., 2009). The degradation of quality in some food is readily visible by changes of texture or colours but there are some situations where the degradation might not be so readily visible. However the visual judgment on current quality is very subjective and not reliable in practice. Therefore the food industry needs appropriate methods to overcome these challenges.

## **THE RESEARCH WORK**

Most of the previous research put their focus on temperature monitoring and management of the products after storage in the refrigerated facilities but placed less emphasis on pre-storage tasks and methods needed for optimal storage conditions. In this paper, we suggest the necessary tasks and methods to do before and after refrigerated storage in cold chain.

### **Analysis on Product Characteristics of the Commodities**

All cold chain products are not the same in terms of lifespan and storage conditions. The variety of the products and the diversified requirement in temperature or humidity contribute to the complexity of cold chain management. Before setting up a cold chain system, it is necessary for logistics managers to know the product characteristic (Zhang, 2007). For fresh fruits and vegetables, it is important to check first on product compatibility. The ideal temperature often depends on the geographic origin of the product. Tropical fruits must be stored above 12°C as they are not compatible to store with temperate one which can be stored at 0°C (Jobling, 2000). The knowledge on product perishability rate also helps to set priority for cooling and storage of the products.

There is a concern to decide whether the supply chain need single or multi commodity cold storage (Kuo and Chen, 2010). Multi commodity cold stores are provided with multiple chambers enabling them to store a wide range of fresh horticulture products together with respect to their storage compatibility requirements for temperature, relative humidity, atmosphere protection from odour and sensitivity to other gases like Ethylene. Also, the refrigeration system is designed to adjust and operate to a range of temperature and humidity conditions, depending on the compatibility group for storage of fruits and vegetables (NHB, 2010). In general, mixed load or storage of perishables is not always recommended as there are concerns with the compatibility of the products such as temperature, RH, Ethylene production/sensitivity, chilling or freezing sensitivity and off- odour or colours due to cross-contaminations. Sometimes problems may not be visible but leads to a loss of quality for the consumer (Martin & Ronan, 2000).

### **Finding Optimal Target Temperature**

Maintaining the desired or ideal holding temperature is a major factor in protecting perishable foods against quality loss during storage and distribution. Quality loss is a function of both time and temperature abuse. Abuse is additive and, even for short periods of time during loading, transit, and unloading, may cause a considerable amount of quality loss by the time the product reaches its destination (Ashby, 2006). There are several temperature levels for food to suit different types of product groups. For example, we might identify frozen, cold chill, medium chill and exotic chill groups (Smith & Sparks, 2004). Thompson and Kader (2001) recommended that fruits and vegetables

should be divided into three groups: 0 to 2°C group; 7 to 10°C group; 13 to 18°C group according to their optimum temperature requirements. The first group is for the majority of the green, non-fruit vegetables and temperate fruits. Groups 2 and 3 refer to chilling-sensitive products.

A single storage area that satisfies to store and keep all chilled products in good quality is almost impossible as the storage of chilled products may cover from 0°C to 18+°C. Two or more refrigerated storage with different temperature zones are necessary to fulfill the temperature requirement of these products. One of the algorithms that suits for that purpose is K-means clustering algorithm. The number of clusters here represents the refrigerated rooms needed for products. We considered applying K-means algorithm on sample dataset of fruits. However, one of its drawbacks is the requirement for the number of clusters,  $k$ , to be specified before the algorithm is applied (Pham et al., 2005). We applied  $k$  values of 2, 3 and 4 to decide the right number of rooms or temperature zones needed for storage (Figure 1.). In our scenario, the following steps were done.

Step 1. K-means clustering is applied on the sample dataset with  $k=2, 3$  and 4.

Step 2. Again, K-means clustering is applied to each cluster with  $k= 2$  for two times but this time, it will be based on two criteria: the total value of produce and the shelf-life.

Step 3. From each pair of value- or shelf life- based sub-clusters, we retrieve the sub-clusters that have maximum total average value and minimum total average shelf life.

Step 4. The centroid value is calculated from the resulting two sub-clusters to get final target optimal temperature range.

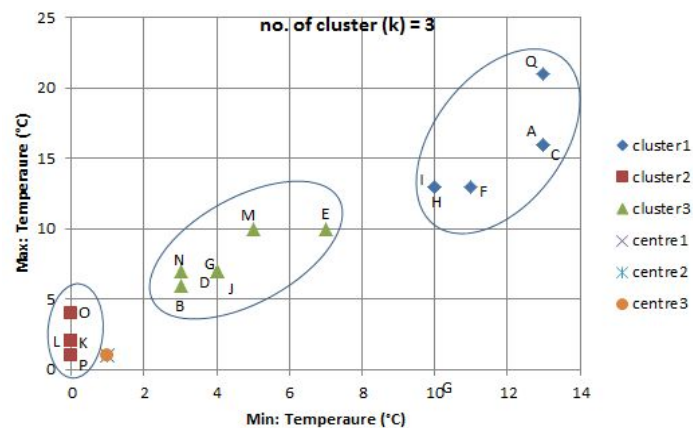


Figure 1. Finding optimal temperature by using K-means ( $k=3$ )

### Quality Assessment of Climacteric Fruit

Fresh fruit and vegetables are living products. After harvest, they continue the process of respiration which produces carbon dioxide, water and heat. In climacteric fruit, the respiration typically rises very rapidly during ripening, and then decreases as the fruit age after its maturity. The rate of deterioration of the produce is largely determined by the rate of respiration which is temperature dependent. Produce which is kept cool will have a low rate of respiration with limited heat production and low rate of deterioration. Different products have different rates of respiration. Those with higher rates are more highly perishable and temperature control is very critical for these products (SARDI, 2006). In general, the storage life of commodities varies inversely with the rate of respiration. This is because respiration supplies compounds that determine the rate of metabolic processes directly related to quality parameters, e.g., firmness, sugar content, aroma, flavor, etc. Measurements of respiration provide an easy, non-destructive means of monitoring the metabolic and physiological state of tissues.



### Freshness Gauge (FG) Calculation for Perishable Foods

The method to calculate freshness is done based on metabolic changes of perishable foods especially in harvested commodities. Freshness is considered alternatively as quality of the product. Initially, the Freshness Gauge (FG) of a new product item after harvest is assumed to be 100%. Then, FG value can be changed whenever the temperature fluctuations happen. The amount of degradation depends on how much real (relative) temperature value is different from ideal (absolute) optimal one. FG is calculated based on product shelf life and current temperature value received from temperature sensor. The value of FG (Eq. 1) can be calculated as follows:

$$FG = \text{Previous FG} - \frac{(\text{New Log Time} - \text{Previous Log Time})}{(\text{Shelf Life} * \text{Weight of Shelf Life})} * 100 \quad (1)$$

### Respiratory Rate (Products' Metabolism) Based Measurement

Temperature data is periodically recorded in short time interval and logged into database. FG value is adjusted according to the values of weight. Weight of shelf life calculation used temperature data which are received by monitoring system.  $Q_{10}$  temperature coefficient was adopted as an indicator to evaluate the quality changes during storage of perishable products (Aung, Chang, & Kim; 2012).  $Q_{10}$  refers to the rate of change of a biological or chemical system as a consequence of increasing the temperature by 10 °C. The  $Q_{10}$  can be calculated by dividing the reaction rate at a higher temperature by the rate at a 10 °C lower temperature, ie.,  $Q_{10} = R_2/R_1$  (Salveit, 2004). The respiration rate is typically measured by emission of Carbon Dioxide (CO<sub>2</sub>) as a mechanism of respiration and is affected by temperature changes. However, the respiration rate does not follow ideal behavior, and the  $Q_{10}$  can vary considerably with temperature. To measure precisely the changing respiration rate and quality degradation, the measurement should be in smaller gap such as 2°C or 3°C. Using this data of measurement for specific commodity, the relative rate of deterioration and relative shelf life can be defined. Four sample of Cavendish banana (Musa acuminata, AAA group) were stored in each temperature controlled chamber at 13, 16 19 and 22°C for 24 hours period. 13°C -16°C is the optimal temperature range to store ripe banana. Based on experimental result of respiration rates (CO<sub>2</sub> emission), we can calculate the relative shelf life for different temperature segment. We consider that the relative shelf life of 13°C ~ 16°C segment is equal to 100% shelf life as it is the optimal temperature condition of Banana in our experiment. Weight of shelf life in Eq.1 is found to decrease as soon as the respiration rate increases (Table 1).

Table 1. Conversion table for Weight of Shelf Life

Temperature segment	Average rate of CO <sub>2</sub> emission (ppm/min)	Relative Shelf Life (%)	Weight of Shelf Life
13°C ~ 16°C	(8.37+10.89) /2= 9.63	100	1
16°C ~ 19°C	(10.89+13.3) / 2= 12.09	79.68	0.8
19°C ~ 22°C	(13.3+17.4) / 2= 15.35	62.89	0.62

### Visual Quality Assessment

Temperature is the key to keep the quality and integrity of product after harvest in cold chain. The effect of temperature on climacteric fruits is demonstrated by climacteric characters such as the changes in respiration rate, colour, texture and flavor etc. The climacteric character represents an important determinant of the ripeness, maturity and storability. Banana is known as a tropical, climacteric fruit that presents fast post-harvest ripening. Inappropriate storage temperature and retail practices can accelerate the quality loss of banana. Therefore, it should be maintained under properly controlled-temperature not to lose the quality throughout the supply chain.

## Colour Measurement Using Digital Images

Colour is one of the most important quality attributes in postharvest food handling and processing, and it influences consumer's choice and preferences. Banana industry today use color charts to judge the skin color of banana as shown in Figure 2. The color of the banana skin is used as an indicator for ripeness or spoilage. A peel color index (scale of 1-7) of banana are divided into 7 levels: Green; Green-trace; More green than yellow; More yellow than green; Green tip; All yellow; Yellow-flecked with brown (Kerbel, 2004).

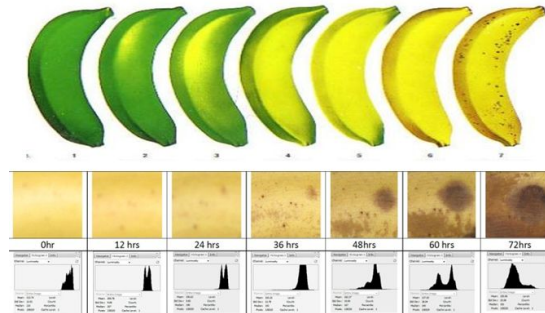


Figure 2. A sample Banana color chart and histograms regarding skin color changes of ripe banana over time

In our experiment, we use four samples of banana (Cavendish group) which has peel color index no. 5. These color charts are useful to judge the peel colors of banana but inspector's decision on quality is rather visual (i.e., subjective) measurement. The instrumental (objective) methods are needed to determine more precisely over the maturity and quality of wide range of food products. There are some devices available such as Colorimeter or Chromameters to measure reflected and transmitted color of objects. Alternatively, digital imaging method is found useful in fresh produce industry to estimate the ripening stages of bananas more accurately (Ji et al., 2012). Measurements were performed at arbitrarily chosen 2cm\*2cm area of banana skin images that we recorded every 12 hrs to identify skin color changes of banana under 24-26°C room environment using histogram (Figure 2). Also the relative color intensity data are collected after measurement of seven consecutive images (Table 2). Then, the level of the ripeness could be easily determined by histogram matching of the measured and standard ripeness stages.

Table 2. The empirical data regarding skin colour changes of ripe Banana over time

Image No.	Luminosity	R	G	B	RGB
1	213.74	242.42	215.85	124.85	194.37
2	205.78	240.1	206.16	110.95	185.74
3	196.63	227.03	197.69	108.79	177.84
4	192.25	223.75	192.17	107.63	174.52
5	162.37	193.46	160.58	88.12	147.38
6	137.21	167.82	133.67	73.68	125.06
7	105.96	136.35	98.76	62.76	99.29

## RESULTS/ANALYSIS

Three methods (i.e. clustering based temperature management, FG calculation to determine current freshness and assessment of quality through monitoring quality parameters) were discussed. In Figure 3, the way how these methods are related in cold chain management is illustrated. The first method includes two steps, i.e., clustering the products for storage and defining optimal target temperatures. Actually, these are preliminary tasks to do for refrigerated storage to achieve optimal setting and not to loss quality. The second method relates to the calculation of freshness to assess the quality changes of the product based on product deterioration rate which can be calculated via

sensors data collected. The third method supports freshness calculation by collecting continuous data over deterioration of product through monitoring of quality parameters by using sensors and reports to user for decision making.

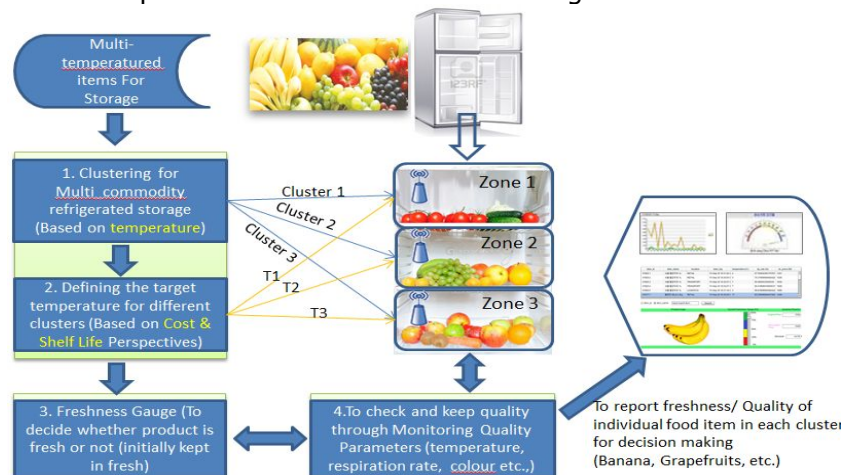


Figure 4. Temperature management and quality assessment flow in cold chain

To assess the quality, we consider two types of measurement using sensors. The first sensor group which includes temperature, humidity etc. is intended for direct sensing to the storage environment and second group which include CO<sub>2</sub>, Ethylene, etc. are used to estimate quality degradation (rate) via metabolic changes which relate to product deterioration process. The FG calculation considers three dimensions (i.e., frequency, deviations and elapsed time) of temperature abuse so estimation for quality status of products in real time monitoring environment could be easily achieved. The visual quality assessment based on colour indicator is useful as an alternative method for verification of quality. Most of the previous research focused on condition monitoring, device management and traceability area but not much focused on product characteristics and optimal setting for monitoring environment. Food industry still use TTI and data loggers commercially for perishable products and the adoption of more efficient WSN-based solution are expected in very near future.

## CONCLUSIONS

This paper presented the important aspects of managing temperature control and product quality in cold chain especially for chilled and chilled sensitive products. The method to improve temperature control is investigated and quality assessment method which is based on products' metabolism is presented for multi-temperature commodities. We applied K-means clustering technique and it is found that divide and conquer the temperature values are effective in managing products that have different temperature requirements. Respiration rate and color changes are presented as two important indicators in quality evaluation of climacteric fruits. The importance of monitoring respiration rate of perishable food is highlighted testing a climacteric fruit, Banana as a sample. To determine the quality status of perishables, using more than one indicator is more preferable. Other important environmental parameters such as humidity and ethylene emission etc. should be considered for further extension. Finally, supply chain are found to be quite complex when dealing with food products, therefore, further research are needed to solve the challenging issues of food supply chain.

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## **Section 13 – Supply Chain Capability Development**

### **A PERFORMANCE MEASUREMENT REFERENCE MODEL FOR LEAN AND GREEN WAREHOUSING - USING FUZZY LOGIC AND THE ANALYTIC NETWORK PROCESS**

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#### **ABSTRACT**

To stay competitive, most companies try to optimize their warehouse processes in order to reduce costs and increase performance. Modern performance measurement concepts have to adapt to current conditions. Therefore, this paper proposes a performance measurement reference model that considers qualitative data and lean as well as green aspects, in addition to financial KPIs. Thus, novel customer requirements can be involved in a performance evaluation of distribution centres. The proposed reference model enables a decision maker to design an individual model by using company specific measures. Interdependencies between measures are explored by using the analytic network process. Fuzzy logic was used to evaluate the reference model based network. The reference model can be used to support the decision making process in distribution centres.

#### **Keywords:**

Performance measurement; Lean warehousing; Green warehousing; Analytic network process; Fuzzy logic

#### **1 INTRODUCTION**

To stay competitive, most companies try to optimize their logistics processes in order to reduce costs and increase performance. In this context distribution centres (DCs) contain a great potential for optimization. Warehouse operations account for between 30 and 50 percent of most companies' supply chain costs [1]. Moreover, distribution centres are the logistics interface for customers. Thus, they contribute significantly to customers' satisfaction by ensuring a high performance of their included logistics processes, which make them to cornerstones of companies' success [1].

In order to determine the scope of optimization of DCs, the performance of the included logistics processes has to be measured. Thus, weak spots can be detected in preparation for appropriate improvement measures. Performance measurement is discussed frequently in literature, but so far the task has been solved only partially [2].

Traditional approaches are based on financial KPIs, which are not appropriate for performance measurement of DCs. Logistics processes are often not value-adding, but make a significant contribution to company's success. Therefore, nonfinancial KPIs should be added to take account of aspects of intangible value [3]. This paper proposes a performance measurement reference model that considers qualitative data and lean as well as green aspects, in addition to financial KPIs. Considering green and lean aspects permits the inclusion of novel requirements of customers and other stakeholders.

The paper is organised as follows: Section 2 presents a literature review on the application of the Analytic Network Process (ANP) and Fuzzy logic within logistics performance measurement. The proposed approach, based on a combination of both, is introduced in section 3. Summary and concluding remarks are outlined in section 4.

## 2 LITERATURE REVIEW

A performance measurement based on ANP and fuzzy logic has considerable benefits compared to traditional methods.

The ANP is a multi-criteria decision making method, which was introduced by Saaty and Takizawa [4, 5]. Wei and Wang claim that the ANP is the most comprehensive framework for analysis of societal, governmental and corporate decisions that is available for decision makers nowadays [6]. Using ANP allows combining quantitative and qualitative data. A unique feature of the ANP – contrary to other methods – is the ability to capture interdependencies and feedbacks between criteria, which are used for performance measurement [7, 8]. Thus, ANP involves developing more complex and dynamic environments with nonlinear relationships – like DCs – for a detailed performance measurement [7, 9].

The fuzzy set theory has been proposed by Zadeh [10]. A performance measurement model based on the fuzzy set theory is able to deal with uncertainty due to imprecision and vagueness [6]. By using the fuzzy set theory insufficient or not quantifiable criteria – e.g. customer satisfaction – can be involved in the performance measurement [11]. Thus, uncertainty caused by incomplete information and complexity of analysed DC processes can be resolved [6].

Despite these abilities, the application of ANP or its combination with the fuzzy set theory was not very common in the past [12]. Nowadays, ANP and the fuzzy set theory are applied in different scopes of performance measurement. They are used to detailed evaluations at the process level – e.g. performance measurement of DC equipment – up to the evaluation of entire supply chains. Exemplary applications will be briefly introduced below.

Ganga and Carpinetti developed a fuzzy based five step prediction model to predict an output performance of a supply chain out of estimated or actual input measure values [13]. The input measures selected by Ganga were derived from measures defined by the SCOR model [13]. By using fuzzy logic causal relations among the measures, which can cross the borders of organisations, were created to model the effect of an input measure – e.g. order-fulfilment – over an output measure like responsiveness. The fuzzy rules of inference, which relate the information that forms the knowledge base in the fuzzy system, were defined by the authors acting as experts [13].

Meade and Sarkis present a model to assess an organisation's logistics strategy compared to alternative strategies by utilizing ANP [9]. The model consists of three different levels: *organizational/supply chain relationship, principles of logistics and attributes of principles of logistics* [9]. The included principles and attributes were determined based on expert opinion and literature [9]. An ANP Network was built up considering levels, principles and various attributes to take potential interdependencies between different elements into account. Following the assessment of the analysed logistics strategies they can be compared. The final result indicates which system meets best the needs of the organisation [9].

The performance measurement model, proposed by Leem et al. is a combination of the balanced scorecard (BSC) and ANP. This approach provides an almost realistic and accurate representation of measuring the performance of DCs [7]. The model consists of three phases. The first phase includes the designing of a BSC for logistics centres. According to the authors, using BSC allows to link the financial and nonfinancial, tangible and intangible as well as internal and external factors [7]. The second phase of the model is to shape an analytic network hierarchy to structure the interdependencies between top-level and sub-level criteria [7]. The third phase is composed of determining KPIs by using the ANP. Decision makers were recruited out of a study group, which consisted of experts from manufacturing, distribution, and logistics firms in Korea [7].

To support the selection process of material handling equipment Tuzkaya et al. developed an adequate multi-criteria decision making method [5]. The method combines ANP, fuzzy sets and the preference ranking organization method for enrichment evaluations (PROMETHEE). In addition to the advantages of ANP and fuzzy, which were already mentioned above the major advantage of the method is the simple and time-saving application of PROMETHEE [5].

The selected papers illustrate that recent performance measurement based on fuzzy logic and ANP is a common method. However, a review of recent publications has shown lean and green aspects in performance measurement are hardly considered.

### **3 THE PERFORMANCE MEASUREMENT REFERENCE MODEL**

The performance measurement is defined in four major steps, which are stated below:

Step 1 Definition of KPIs and measures: The performance measurement reference model is developed to be applied in distribution centres. The performance of a distribution centre is defined through KPIs, which could be derived from customer requirements. The implementation of a high *delivery service* can be identified as the superior customer requirement. According to Pfohl and Zöllner a high delivery service includes the components *short lead time, high delivery reliability, high delivery quality and high delivery flexibility* as goals for the operation of a distribution centre [14]. These components are supposed to be used as KPIs in the proposed reference model. In order to integrate novel customer requirements in the performance measurement the KPIs *Leanness* and *Greenness* have been considered.

The KPIs could be defined by means of different measures. In literature there is no consensus among experts on which measures should be used to evaluate the performance of DCs. Therefore, the measures, which are proposed in this paper, are not fixed. The performance can be evaluated either with the proposed measures, or experts fill the reference model with company specific measures. Through this case-specific adaptation the reference model can be customized for each DC. Based on a literature review a multitude of measures were identified. Due to expert interviews the number of proposed measures could be limited to an appropriate amount, Table 1.

Step 2 Aggregation of the measures to KPIs with fuzzy logic:

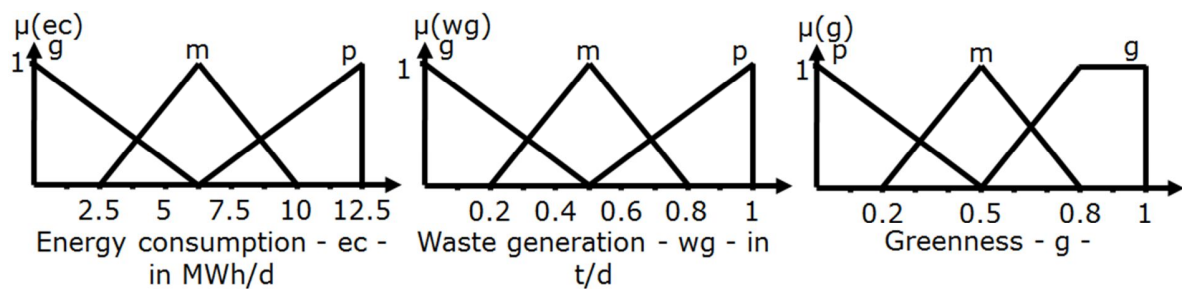
Step 2.1 Definition of fuzzy sets and associated membership functions: Fuzzy sets and associated membership functions have to be defined by experts for each linguistic variable. The linguistic variables represent the measures shown in Table 1 (input variables) or the KPIs as defined above (output variables). The fuzzy sets, defined by a membership function,



express the numeric value of the variable qualitatively as linguistic terms. The *Energy consumption*, for example, is a linguistic input variable whose values can be: poor, medium or good [13]. In general, any variable can be described by any number of fuzzy sets. The authors recommend that the number of fuzzy sets is limited to an appropriate level to limit the aggregation effort. Figure 1 shows exemplary fuzzy sets of two variables and a KPI. Table 2 shows the corresponding membership functions. Based on the definition of the membership functions of input and output variables, it is possible to define the fuzzy rules.

<b>Measure types</b>	<b>Incoming goods area</b>	<b>Warehouse and picking area</b>	<b>Consolidation and packing area</b>	<b>Outgoing goods area</b>
<b>Structural measures</b>	Number of employees Number of equipment	Number of employees Number of equipment Inventory Storage capacity Filling degree of storage Number of articles per packing unit	Number of employees Number of equipment	Number of employees Number of equipment
<b>Performance measures</b>	Employee productivity Equipment productivity Throughput	Employee productivity Equipment productivity Throughput	Employee productivity Equipment productivity Throughput	Employee productivity Equipment productivity Throughput
<b>Costs measures</b>	Operating costs	Operating costs	Operating costs	Operating costs
<b>Quality measures</b>	Delivery date deviation Error ratio Loss ratio Number of accidents	Delivery date deviation Error ratio Loss ratio Number of accidents	Delivery date deviation Error ratio Loss ratio Number of accidents	Delivery date deviation Error ratio Loss ratio Number of accidents
<b>Environmental measures</b>	Energy consumption Waste generation	Energy consumption Waste generation	Energy consumption Waste generation Packing materials per shipping unit	Energy consumption Waste generation

**Table 1: Proposed measures structured according to organisational units**



**Figure 1: Exemplary fuzzy sets**

Input/output variables	Unit	membership functions and linguistic terms		
		p: poor	m: medium	g: good
Energy consumption	MWh/d	(6.25;0) (12.5;1)	(2.5;0) (6.25;1) (10;0)	(0;1) (6.25;0)
Waste generation	t/d	(0.5;1) (1;1)	(0.2;0) (0.5;1) (0.8;0)	(0;1) (0.5;0)
Greenness	membership	(0;1) (0.5;0)	(0.2;0) (0.5;1) (0.8;0)	(0.5;0) (0.8;1) (1;1)

**Table 2: Exemplary membership functions corresponding Figure 1**

Step 2.2 Definition of fuzzy rules: Fuzzy rules include the information that forms the knowledge base of the fuzzy system [13]. The fuzzy rules are defined by experts to determine the correlation between input and output variables. To derive the KPI *Greenness* from the measures *Energy consumption* and *Waste generation* the rules can be formulated as follows:

If *Energy consumption* is  $x_i$  and *Waste generation* is  $y_i$  then *Greenness* is  $z_i$ .

Table 3 shows the potential value variations of the input and output variables corresponding the fuzzy rules and fuzzy sets mentioned above.

Rule i:	1	2	3	4	5	6	7	8	9
$x_i$	good	good	good	Medium	medium	medium	poor	poor	poor
$y_i$	good	medium	poor	Good	medium	poor	good	medium	poor
$z_i$	good	good	medium	Good	medium	poor	medium	poor	poor

**Table 3: Fuzzy rules for evaluate of the KPI Greenness**

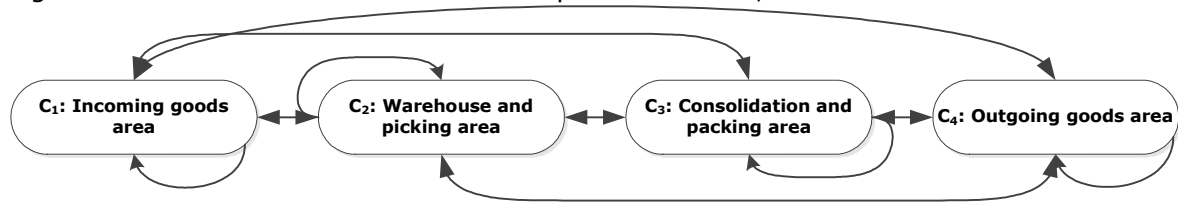
Step 2.3 Evaluations of the KPIs: If the numerical values of the input variables are known, they can be fuzzified by using membership functions. The fuzzified input variables can be combined based on the defined fuzzy rules. In application of the Mamdani method and the centre-of-gravity method the numeric output values of the KPIs ( $v_{ij}$ , where  $i$  is the index of the component the KPI belongs to and  $j$  is the index of the KPI, Table 4) can be determined from the fuzzy input values [16]. An exemplary evaluation of the KPI *Greenness* out of the measures *Energy consumption* and *Waste generation* using Matlab is shown in Figure 2.



**Figure 2: Evaluation of the KPI Greenness using Matlab**

Step 3 Determining global weights for the KPIs with ANP:

Step 3.1 Modelling a decision network: A decision network needs to be created by experts and consists of components, elements and interdependencies. In this case the components correspond to the organizational units of a DC and are made up of their respective elements, Figure 3 and Table 4. The elements are equal to the KPIs, which were defined above.



**Figure 3: Exemplary decision network**

Components $C_i$	Elements	$e_{i,j}$	Components $C_i$	Elements	$e_{i,j}$
C <sub>1</sub> : Incoming goods area	lead time	$e_{1,1}$	C <sub>3</sub> : Consolidation and packing area	lead time	$e_{3,1}$
	delivery reliability	$e_{1,2}$		delivery reliability	$e_{3,2}$
	delivery quality	$e_{1,3}$		delivery quality	$e_{3,3}$
	delivery flexibility	$e_{1,4}$		delivery flexibility	$e_{3,4}$
	Leanness	$e_{1,5}$		Leanness	$e_{3,5}$
	Greenness	$e_{1,6}$		Greenness	$e_{3,6}$
C <sub>2</sub> : Warehouse and picking area	lead time	$e_{2,1}$	C <sub>4</sub> : Outgoing goods area	lead time	$e_{4,1}$
	delivery reliability	$e_{2,2}$		delivery reliability	$e_{4,2}$
	delivery quality	$e_{2,3}$		delivery quality	$e_{4,3}$
	delivery flexibility	$e_{2,4}$		delivery flexibility	$e_{4,4}$
	Leanness	$e_{2,5}$		Leanness	$e_{4,5}$
	Greenness	$e_{2,6}$		Greenness	$e_{4,6}$

**Table 4: Components and Elements of the decision network**

Step 3.2 Modelling of a raised to power supermatrix: Interdependencies within the network can be captured by pairwise comparison of components or elements [12]. From the pairwise comparison of the components priority vectors can be derived and combined in the matrix  $Q$ , Figure 4. The priority vectors derived from the pairwise comparison of the elements are arranged as columns in blocks  $W_{ij}$  [7]. Each priority vector in  $W_{ij}$  includes the influence of the elements in the  $i_{th}$  component of the network on an element in the  $j_{th}$  component, Figure 4 [17]. All  $W_{ij}$  form the unweighted supermatrix  $W$ .

$$Q = \begin{bmatrix} q_{11} & q_{1j} & \cdots & q_{1m} \\ q_{i1} & q_{ij} & \cdots & q_{im} \\ \vdots & \vdots & \ddots & \vdots \\ q_{m1} & q_{mj} & \cdots & q_{mm} \end{bmatrix}$$

$$W_{ij} = \begin{bmatrix} W_{i_1j_1} & W_{i_1j_2} & \cdots & W_{i_1j_n} \\ W_{i_2j_1} & W_{i_2j_2} & \cdots & W_{i_2j_n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{i_nj_1} & W_{i_nj_2} & \cdots & W_{i_nj_n} \end{bmatrix}$$

$$W = \begin{matrix} & \begin{matrix} C_1 & C_2 & \cdots & C_m \end{matrix} \\ \begin{matrix} e_{11} & \cdots & e_{1n_1} & e_{21} & \cdots & e_{2n_2} & \cdots & e_{m1} & \cdots & e_{mn_m} \end{matrix} \\ \begin{matrix} C_1 \\ \vdots \\ e_{1n_1} \\ e_{21} \\ C_2 \\ \vdots \\ e_{2n_2} \\ \vdots \\ e_{m1} \\ C_m \\ \vdots \\ e_{mn_m} \end{matrix} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1m} \\ W_{21} & W_{22} & \cdots & W_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ W_{m1} & W_{m2} & \cdots & W_{mm} \end{bmatrix} \end{matrix}$$

**Figure 4: supermatrix and block of the supermatrix [15]**

To assess the influence of each element on every other element in the network the weighted supermatrix  $U^{un}$  is calculated by multiplying each  $W_{ij}$  by the corresponding  $q_{ij}$ . By deviating  $U^{un}$  the column stochastic supermatrix  $U$  is derived. Raising  $U$  to the power of  $k$  allows convergence, where  $k$  is an arbitrarily large number [12]. The converged supermatrix  $U^k$  includes a stable set of global weights ( $g_{ij}$ ), which specify the importance of every element in the network taking each interdependencies into account.

Step 4 Evaluation of DC's performance: First the experts have to formulate target-setting of each KPI ( $s_{ij}$ ). These settings provide information about the required values. By dividing  $v_{ij}$  by  $s_{ij}$  the target achievement ( $a_{ij}$ ) is calculated:

$$a_{ij} = \begin{cases} \frac{v_{ij}}{a_{ij}} & \text{for } \frac{v_{ij}}{a_{ij}} \leq 1 \\ 1 & \text{for } \frac{v_{ij}}{a_{ij}} > 1 \end{cases}$$

If a target-setting is exceeded,  $a_{ij}$  is set on 1. Thus, an exceeding of one KPI can not hide the deterioration of another. Hereinafter the performance share ( $p_{ij}$ ) of each KPI of the total performance is calculated by multiplying  $a_{ij}$  by the corresponding global weight  $g_{ij}$ . The performance ( $P$ ) of the distribution centre is the sum of each  $p_{ij}$ :

$$P = \sum_{i=1}^m \sum_{j=1}^n p_{ij}$$

Due to the restriction of the interval of the target achievement to  $a_{ij} = [0,1]$  and the normalization of the global weights to 1, the value of the performance is within the interval  $P = [0,1]$ . If the performance reaches a value of 1 all target-settings are fulfilled.

## 4 SUMMARY AND CONCLUSION

Distribution centres have a great potential of optimization. In order to explore the scope of optimization a performance reference model was developed. Lean and green aspects were implemented to consider novel customer requirements while evaluating the performance. Due to the missing consensus among experts on which indicators should be used for performance measurement measures were proposed, which were identified based on a literature review. With the ability to add more measures, the reference model allows a case-specific adaptation. Fuzzy logic was used to aggregate the measures and evaluate the KPIs of the reference model. By using ANP, the KPIs could be aggregated to a performance value by taking all relevant interdependencies into account. Combining Fuzzy logic with the Analytic Network Process prevents unnecessary extensive calculation in the evaluation of DC's performance.

The proposed reference model can be used to support the decision making process in distribution centres.

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# HOW TO STRUCTURE LOGISTICS EDUCATION: INDUSTRY QUALIFICATIONS FRAMEWORK OR TOPICAL STRUCTURE?

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## CATEGORY: RESEARCH PAPER

### Keywords

Logistics Education, Berufswertigkeit, Industry Qualifications Framework (IQF) Logistics

### INTRODUCTION

The dynamic development of logistics processes and concepts is driven by many factors such as globalization, technology innovation and implementation, societal and individual needs as well as resource limitations and increasing environmental sustainability requirements in the future (cp. Klumpp/Clausen/ten Hompel, 2013). Within this outlook an important question is the topic of *logistics education*: Logisticians' competences may be one of the deciding factors for resource-efficient and effective logistics regarding the conflicting expectations of individuals and societies as well as national and global policies, therefore qualification topics have to be identified as early as possible (Baron/Zweck, 2010). For the further structuring and standardization necessary to achieve acceptable efficiency and impact levels throughout the logistics industry *two approaches* have been named and have to be evaluated regarding the practical requirements of logistics companies and processes (cp. Roth, 2012):

- (a) A qualifications framework approach as suggested in general for all education and qualification systems by the European Commission – especially with the objective of reconciling academic and vocational education sectors in Europe; this was outlined from 2010 onwards as Industry Qualifications Framework concept for logistics (cp. Klumpp/Keuschen/Peisert, 2010).
- (b) Alternatively a topical structure could be used to lists competence requirements according to different fields and subtopics e.g. as in the field of humanitarian logistics (cp. Kovacs/Tatham/Larson, 2012); this could be detailed by any means for the further fields of *industries* (retail, steel, chemical logistics etc.) or *functions* in logistics (inbound, outbound logistics etc.).

The decision between the two structuring approaches is addressed by conducting a SWOT analysis for both approaches (based on practical requirements as described by Roth as well as the 2012 Berufswertigkeit evaluation results from Germany), followed by an integration test – a feasibility study if the two approaches could possibly be merged into a combined approach. Both methods will bear interesting results for future logistics education research. The question of how to structure logistics education for the future has never been discussed and analysed by the help of a SWOT analysis and based on these two approaches as described. Education and competence evaluation in logistics has to be improved and structured further in order to reach a level of international comparative feasibility in order to enhance quality in the international education market regarding logistics qualification – spanning all sectors like academic, vocational and continuing education world-wide. This may improve the overall education productivity and therefore the individual return-on-education for individuals and companies in logistics.

Large-scale as well as smaller logistics companies are in need for further structuring of their professional development of human resource concepts and resource allocation decisions. This could be aided by the described approach and research results.

### **QUALIFICATIONS FRAMEWORKS AND LOGISTICS**

Since 2003 a new development in education and qualifications contexts can be observed: The advent and implementation of qualifications frameworks (QF), triggered by the European Qualifications (EQF) concept published by the European Commission in this same year (European Parliament, 2008). During the last decade, this concept was mainly implemented on the national education *policy levels*, for example in 2012 in Germany (Gehmlich, 2009; Bjornavold/Coles, 2010). This development is based on the idea to integrate all education and qualification streams and institutions, from schools to vocational training to academic education into one comprehensive framework. A further development in the last years have been the *industry-specific and therefore also slightly topical-oriented approaches* to develop specific Industry Qualifications Frameworks, e.g. an Industry Qualifications Framework for logistics in 2010, revised in 2013 (Klumpp/Keuschen/Peisert, 2010; Klumpp et al. 2013).

In order to contribute to the before outlined research gap this mainly qualitative approach has to be complemented with a quantitative evaluation concept. Since 2007, for exactly this purpose the output-oriented measuring concept "*Berufswertigkeit*" has been developed and served also as an industry evaluation concept for the development of an Industry Qualifications Framework for the logistics industry, e.g. also the EU ESCO reference group "transportation and storage" (Klumpp 2007; Klumpp/Schaumann, 2007). The 36 evaluation criteria of this concept are listed here:

- Efficiency
- Independence and own initiative
- Flexibility and adaptability
- Work virtues
- Stress resistance
- Motivation and ability to lifelong learning and maintain to own competence profile
- Coordinate the work- and lifetimes
- Creativity
- Loyalty
- Risk-taking
- Charisma
- Ability to write and speak in German
- Knowledge for foreign language
- Ability to apply modern information- and communication technologies (work place)
- Communication and rhetoric
- Assertiveness
- International and intercultural competence
- Customer focus
- Skills in mathematics and statistics
- Preparation of cost estimates and quotations
- Planning, implementation and documentation of orders and projects
- Negotiations capacity
- Analytical problem-oriented work
- Quality management (optimization of processes and products or service quality)
- Conceptual and strategic implementation of industry-specific knowledge and experience
- Identification with the company
- Strategic orientation, determine / control the complete company
- Understanding solutions of complex technical problems



- Basic knowledge of business administration
- Perception of functions of management and organization
- Conceptual working in immediate workplace
- Planning and control procurement and logistics processes
- Staff requirements and staff mission planning / staff development
- Team, staff and leadership
- Improving responsible care
- Legal knowledge

Since the end of June 2011 and into 2012 a field survey with 1,068 persons from the logistics industry within the German research project "Wissenschaftliche Weiterbildung in der Logistik" (EffizienzCluster LogistikRuhr) was started. There are three types of survey instruments which could be executed such as written form, telephone and internet. Due to the experiences in the two Berufswertigkeit studies of 2007 and 2009 the project consortium decided for a telephone survey. The survey was executed in North Rhine-Westphalia and Hesse as both states depict a very good representation of the whole country of Germany (economic and population structures). Since January 2011 the survey was in preparation by development of the survey instrument, addresses of the logistic industries in both states, distribution of qualification in the logistic industry, questionnaire, pretests and selection of the institute for questioning. The telephone survey of more than 1,000 persons had been begun on the end of June and took place till September 2012. 808 persons in North-Rhine Westphalia (NRW) and 259 persons in Hesse with different education levels were questioned. Therein existing skills and competences of persons in the logistics industry will be described and the above mentioned draft for an industry qualifications framework logistics will be reworked. Also traditional formal degrees in vocational and academic education will be classified according to evaluated practical competence levels. In total 1,068 persons from the logistics industry were questioned and these represent 379 female and 689 male respondents.

Altogether 75.7% of the respondents are from North Rhine-Westphalia and the remaining 24.3% are from Hesse. The respondents represent various professional levels at their current working place. 88.6% are employed as white-collar worker in the different levels like branch manager, team leader and office clerk in their company and 11.4% work in the warehouse or as truck drivers, namely blue-collar workers. The figure 2 shows the Berufswertigkeitsindex which significantly presents that 80% of the competences of 21.8% blue-collar as well as white-collar workers in Hesse are higher evaluated than blue-collar as well as white-collar workers in North-Rhine Westphalia, hereby it is to assume that the German federal state of Hesse indicates a very specialized logistics area with "hotspots" such as e.g. Frankfurt Airport.

The following figures show results from this survey in the specific shape of group distribution functions, allowing for a comparison of groups of different sizes as on the y-axis percentage shares of the group total in percent are depicted regarding the different levels of people meeting the "Berufswertigkeitsindex" (BWI) competence requirement criteria (36 criteria normalized onto an 100 percent scale).

With this application it can be shown that specific characteristics such as the school degree and therefore a specific amount of education have specific, positive effects on the level at which people meet the Berufswertigkeit criteria (figure 5). This can be interpreted as competence level regarding specific groups or persons. Also in a further analysis non-formal education aspects as for example the training-on-the-job effect ("experience") can be measured as shown in figure 6 – where persons with more business experience state higher levels in the BWI measurement concept than others. This could enable companies even to simulate the prognostic competences of employees in the future or after specific education and training measures (prognosis on BWI increase in the future).

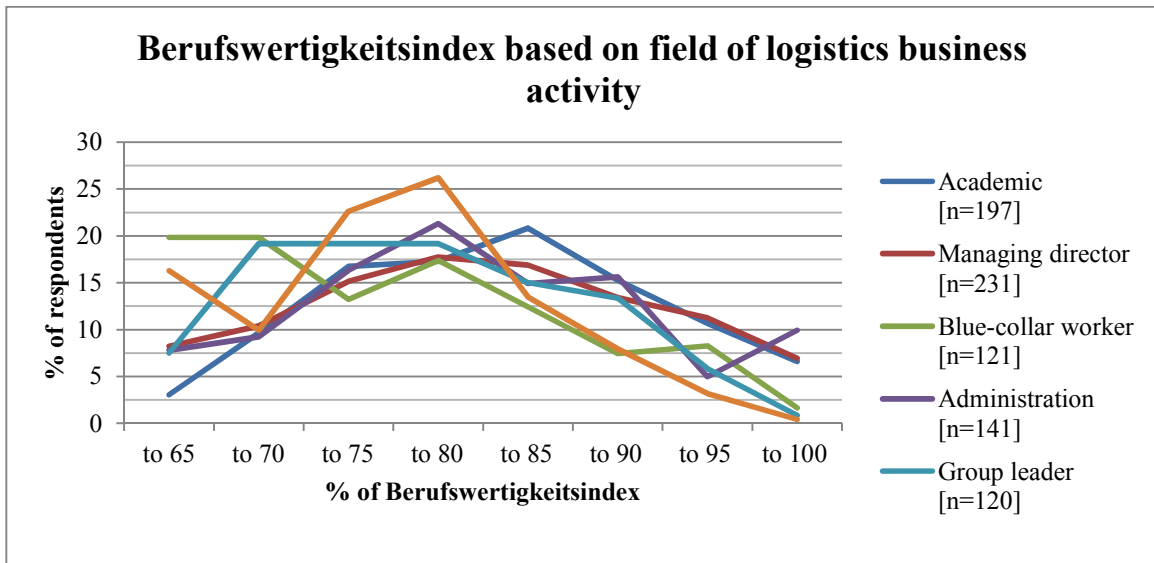


Figure 1: BWI Criteria and Total BWI Distribution among all Persons

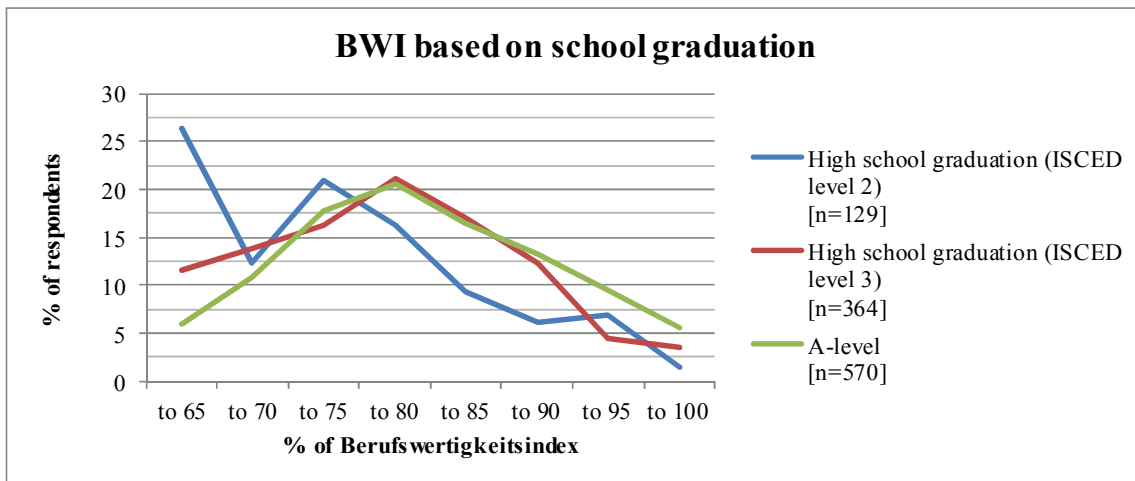


Figure 2: Total BWI Distribution According to School Degree

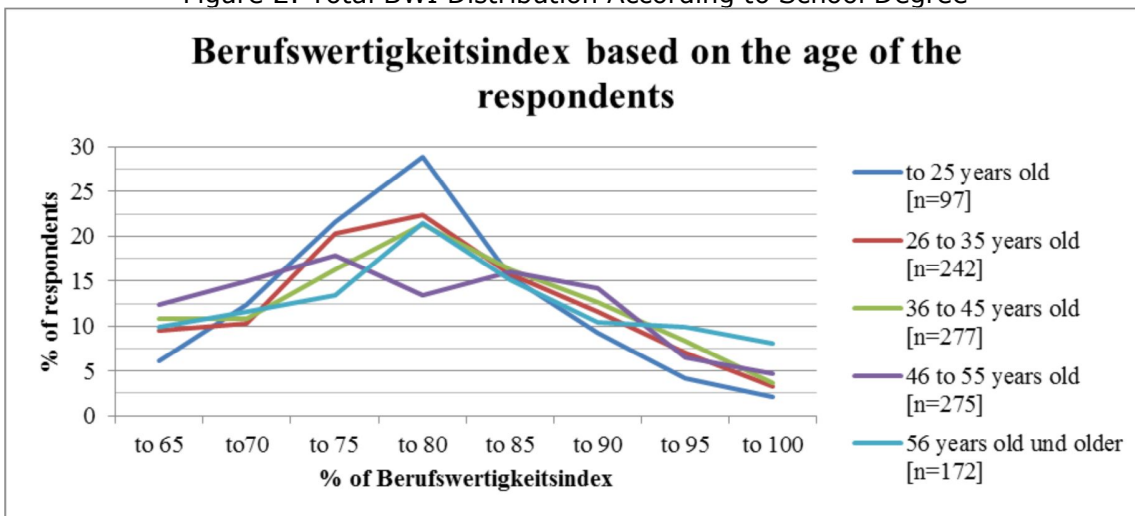


Figure 3: Total BWI Distribution According to Age

An example for a previously deducted Industry Qualifications Framework for logistics can be taken from the field of humanitarian logistics as listed below (Bölsche/Klump/Abidi, 2013):

Level	KNOWLEDGE	SKILLS	COMPETENCE
	In the context of EQF, knowledge is described as theoretical and/or factual.	In the context of EQF, skills are described as cognitive (involving the use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments).	In the context of EQF, competence is described in terms of responsibility and autonomy.
Level 1	basic knowledge in logistics in particular humanitarian logistics such as background of humanitarian relief and humanitarian logistics process	basic skills required to carry out simple tasks e.g. load and unloading process of transport unit at the airport in the disaster area according to instructions	work or study under direct supervision in a structured context and knowledge of English language and basic knowledge in another foreign language e.g. Spanish or French
Level 2	basic factual and general knowledge of a field of work or study e.g. the actors of humanitarian relief operations, the different activities of NGO's and GO's as well as the tasks of military services	basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools e.g. knowledge about the SPHERE rules and conditions, knowledge how to fill in different lists for the inventory management of humanitarian goods	work or study under supervision with some autonomy e.g. development of contingency plans, working in warehouses (loading and unloading processes)
Level 3	knowledge of facts, principles, processes and general concepts, in a field of work or study e.g. fleet management or airport management in case of a disaster	a range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, material and information e.g. customs clearance, procurement, transportation and inventory management	take responsibility for completion of tasks in work or study adapt own behavior to circumstances in solving problems e.g. negotiating with supplier about transport conditions and organizing transport
Level 4	factual and theoretical knowledge in broad contexts within a field of work or study e.g. design of a humanitarian logistics plan, organizing human resources for supporting the teams in a disaster country	a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study e.g. planning volunteers, budgets or employees in a disaster country	exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities e.g. negotiating with suppliers, logistics provider, UNICEF, WFP or adapting commercial logistics concepts and implement it in humanitarian logistics after evaluation and redesign
Level 5	comprehensive, specialized, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge e.g. developing a new humanitarian logistics concept and implement it	a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems e.g. using different complex methods and tools for solving humanitarian logistics concepts or verifying which ICT innovation promotes efficiency in a humanitarian logistics chain	exercise management and supervision in contexts of work or study activities where there is unpredictable change review and develop performance of self and others e.g. supervising and management of inventories, warehouse or fleet in a disaster field
Level 6	advanced knowledge of a field of work or study, involving a critical understanding of theories and principles, e.g. developing and implementation of logistics education and training	advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work or study e.g. developing ICT tools, developing a last mile distribution concept in relief operations	manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts take responsibility for managing professional development in humanitarian relief sector of staffs in field of an affected country
Level 7	highly specialized knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research critical awareness of knowledge issues in a field and at the interface between different humanitarian fields e.g. joint sourcing, financial flows or global warehousing	specialized problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields e.g. developing performance management tools for the humanitarian logistics sector	manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
Level 8	knowledge at the most advanced frontier of a field of work or study and at the interface between fields, e.g. about future logistics and information systems in humanitarian logistics or transport networks in disaster relief operations	the most advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research e.g. use of GNSS systems in humanitarian logistics

Table 1: Example IQF Logistics (Humanitarian Logistics)

## TOPICAL STRUCTURE AND LOGISTICS

Topical structures for logistics education and qualification can be found in many places, first and foremost in curricula and exam regulations. The two following examples of an academic program (master program in logistics, Erasmus University of Rotterdam) and vocational education (German further vocational training "Logistikmeister") show an outline of this approach, directed at a comprehensive oversight regarding necessary qualification areas.

	Student Workload
Two seminars, to be chosen from: <a href="#">Seminar Port Economics and Global Logistics</a> , <a href="#">Seminar Urban Economics and Management</a>	24 ECTS credits (12 ECTS credits per seminar)
<a href="#">Seminar Supply Chain Management and Optimization</a> , <a href="#">Seminar Industrial and Regional Economics</a>	
<a href="#">Quantitative Methods for Applied Economics</a>	4 ECTS credits
Two courses, to be chosen from: <a href="#">Transport Economics and Policy</a> <a href="#">Port Economics</a> <a href="#">Economics of Strategy</a> <a href="#">Urban Economics and Real Estate</a> <a href="#">City Marketing</a> <a href="#">Strategic Management of the Transport and Logistics Firm</a>	8 ECTS credits (4 ECTS credits per course)
One elective, to be chosen from: either the courses mentioned above or, Master's courses of RSM Supply Chain Management	4 ECTS credits
One elective, to be chosen from: Master's courses of the ESE (including any of the courses mentioned above)	4 ECTS credits
Master's thesis	16 ECTS credits
Programme	60 ECTS credits

Table 2: Academic Curriculum Logistics (Erasmus University of Rotterdam, 2013)

English (Translation by the Author)	German (Bundesministerium der Justiz, 2013)
<p>Within the qualification focus „logistics performance“ the competence shall be examined, if the person is able to organize the material flow from inbound to outbound transports, including packaging and stuffing as well as return shipments, according to company and legal requirements. Within this objective the following specific points may be examined:</p> <ol style="list-style-type: none"> <li>1. Organization of inbound shipments and initialization of return shipments if necessary;</li> <li>2. Steering and control of warehouse intake and shipment inspection;</li> <li>3. Organization of shipment consolidation and special services for individual shipments;</li> <li>4. Selection of transport mode and packaging;</li> <li>5. Organization of corporate and long-distance transport including necessary documents;</li> <li>6. Organization of transshipment;</li> <li>7. Recognition and application of relevant legal rules.</li> </ol>	<p>„Im Qualifikationsschwerpunkt „Leistungserstellung“ soll die Fähigkeit nachgewiesen werden, unter Berücksichtigung betrieblicher und gesetzlicher Vorgaben den Materialfluss vom Wareneingang bis zum Warenausgang einschließlich aller auftragsbezogenen Tätigkeiten zu organisieren, die ordnungsgemäße Verpackung und Verladung sicherzustellen, den weiteren Transport zu planen und Reklamationen zu bearbeiten. In diesem Rahmen können folgende Qualifikationsinhalte geprüft werden:</p> <ol style="list-style-type: none"> <li>1. Organisieren des Wareneingangs und Veranlassen der Reklamationsbearbeitung;</li> <li>2. Steuern und Überwachen der Einlagerung und der Warenpflege;</li> <li>3. Organisieren der Kommissionierung und auftragsbezogener Leistungen;</li> <li>4. Auswählen der Versandart und Festlegen der Verpackung;</li> <li>5. Organisieren des innerbetrieblichen und außerbetrieblichen Transports einschließlich der Dokumente;</li> <li>6. Organisieren des Güterumschlags;</li> <li>7. Berücksichtigen der rechtlichen Rahmenbedingungen.“</li> </ol>

Table 3: Vocational Federal Exam Regulation "Logistikmeister" in Germany (Bundesministerium der Justiz, 2013)

## SWOT ANALYSIS

The following two tables outline the comparative SWOT analysis of the two described approaches regarding the structure of logistics education in order to derive suggestions.

<b>Strengths</b> - Integration of educational sectors (academic, vocational, informal learning) - Learning motivation and orientation through level structure	<b>Weaknesses</b> - No topical content (first level structure) - No immediate reference to work and task structures
<b>Opportunities</b> - General trend in political concepts regarding education and qualification	<b>Threats</b> - (Failing) acceptance of overall political development

Table 4: SWOT Qualifications Framework Approach

<b>Strengths</b> - Derived from work structures (tasks) - Explanatory power due to specific topics and tasks	<b>Weaknesses</b> - Without qualification and also requirement levels - Missing motivation structure (personal and organizational improvement)
<b>Opportunities</b> - Embedded in all educational systems - Rising importance in Bologna and accreditation processes	<b>Threats</b> - Increasing interdisciplinary approach in logistics - Possibly questioned by outcome objectives

Table 5: SWOT Topical Approach

## INTEGRATIVE APPROACH

An integrative approach combining the qualifications framework and topical structure approaches can be depicted in table 6 in order to start a discussion in this direction.

	Inbound Logistics	Inhouse Logistics	Outbound Logistics
Level 1	Implementation of simple tasks under direction in factory and warehouse intake of shipments including necessary documentation and return shipments if necessary	Implementation of simple tasks under direction in factory/facility inhouse transport including warehouse tasks, material handling tasks as well as picking and packing tasks	Implementation of simple tasks under direction in distribution shipments including application of transport mode and shipment packaging
Level 2	Implementation of regular tasks in factory and warehouse intake of shipments including necessary documentation and return shipments if necessary	Implementation of regular tasks in factory/facility inhouse transport including warehouse tasks, material handling tasks as well as picking and packing tasks	Implementation of regular tasks in distribution shipments including application of transport mode and shipment packaging
Level 3	Analysis and implementation of regular as well as new tasks in factory and warehouse intake of shipments including necessary documentation and return shipments	Analysis and implementation of regular as well as new tasks in factory/facility inhouse transport including warehouse tasks, material handling tasks as well as picking and packing tasks	Analysis and implementation of regular as well as new tasks in distribution shipments including application of transport mode and shipment packaging
...			

Table 6: Integrative Approach (Draft)

## CONCLUSIONS AND OUTLOOK

The article has shown that two approaches regarding the top-level structure for logistics education are feasible and already in use. A comparative SWOT analysis showed strengths and weaknesses for both approaches, therefore the drafted integrative approach may be interesting for future research and business practice in logistics.

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# **SUPPLIER DEVELOPMENT – SCOPE AND ISSUES IN EMERGING ECONOMIES**

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## **ABSTRACT**

The aim of this study is to assess the state of supplier development activities being carried out in an emerging economy. This study is part of a larger project to identify the issues and barriers related to supplier development and reasons of those barriers. This study is focused towards exploring the supplier development activities across different industries, the role of facilitating activities and the impact of barriers. Since the nature of this study is exploratory, a qualitative approach for data collection was selected. The initial results point out a set of common activities present along all cases showing their importance in supplier development framework. These include supplier visits, inviting suppliers to observe the process at buyers' location and having a supplier evaluation procedure in place. In addition this study highlights the importance of having a firm contract in place in addition to explicitly communicating the future potential to the suppliers. The main limitation is the small sample size and the lack of generalizability of the results.

## **INTRODUCTION**

Globalization has resulted in increased international competition but at the same time, there have been development in technology, processes and organizational practices. This has been complemented by a move towards "de-integrated" structures entailing focused approach towards the core competencies and working with partners across organizational boundaries to deliver value to end customers. This has increased the dependence upon channel partners and no single player can individually attain the results. Also it's not like organizations competing against organizations but supply chains competing against each other for the share of the business. For creating a successful supply chain and collaborative buyer/supplier relationship, supplier development is the emerging concept. For example, Toyota is the pioneer and has initiated this concept, and other organizations have followed this benchmark for their own development as well as for the supply chain (Marksberry, 2012). There have been a lot of work done on this issue in west, but research perspective of emerging economies is lagging behind. So this research is focused towards supplier development in emerging economies.

## **LITERATURE REVIEW**

### **Supplier Development**

For Watts and Hahn (1993), supplier development encompassed "a long-term cooperative effort between a buying firm and its suppliers to upgrade the suppliers' technical, quality, delivery, and cost capabilities and to foster ongoing improvements". The decisive aim of these activities was to build a platform to nurture the relationship in the benefit of both organizations in order to compete successfully in the market. Krause et al. (1998) identified strategic supplier development process, using a ten-step model, starting with critical commodities identification for development to the final goal of continuous improvement. Moreover, two approaches, process oriented and result oriented, were applied at each step to access the firm's motive whether to proactively manage supplier and/or to respond to certain situation. The process oriented or broad perspective referred to a long term and proactive collaboration to enhance the capabilities (technical, quality, delivery and cost) of suppliers on continuous basis, whereas result oriented or narrow perspective referred to a

reactive approach to create a new sources of supply when current supply basis was unable to satisfy the firm's requirements (Hahn et al., 1990). According to Prahinski and Benton (2004), effective result of SD activity could be achieved only if supplier showed commitment and buying firm could influence it through collaborative communication, cooperation and commitment. Other factors for effective SD program included adaptation level, power, resource dependence, trust, uncertainty avoidance and supplier strategic objectives (Krause and Ellram, 1997; Williams, 2006; Ambrose et al., 2010 and Humphreys et al., 2011).

### **Supplier Development Activities**

Most of the literature identified the supplier development processes and activities in the context of western world. Hahn et al. (1990) developed a comprehensive matrix of supplier development activities, which covered two aspects; supplier performance capabilities and areas for improvement. Supplier performance capabilities incorporate technical, quality, delivery and cost issues, whereas the performances areas include product, process or operation system. The supplier development matrix could be developed by combining these two factors. This matrix could provide guidance for companies to identify specific areas that require improvement with suppliers. Krause and Ellram (1997) identified several supplier development activities including use of fewer (2 or 3) suppliers to create competition, informal and formal evaluation, feedback, use of a supplier certification program, verbal or written request to improve performance, promise of current and future benefits, site visits, inviting supplier's personnel, recognition, training and direct investment in the supplier's operation. The study concluded that the firm which stated its SD efforts satisfactorily was likely to reap more benefits and had proactive approach regarding supplier performance. Further in-depth analysis of literature revealed different categories of above stated supplier development activities. According to Krause (1997), supplier development activities could be divided into three forms; direct involvement, incentive based and enforced competition. Direct involvement showed more willingness of buying firm in supplier development and such activities include evaluation programs, site visits, feedback etc (Hartley and Jones, 1997; Wen-li et al., 2003; Wagner, 2006). Incentive based activities included promise of current and future business that showed firm's commitment if supplier improves its performance, whereas enforced competition covers activities such as use of 4 or more supplier or use of 2 or 3 suppliers to build competition which showed less commitment from buyer's side (Krause, 1997; Sanchez-Rodrigues, 2005; Wagner, 2006).

### **Barriers and challenges in Supplier Development**

In literature, very few studies reported the barriers and issues faced by both purchaser and supplier during supplier development activities. The study of Krause et al. (1999) discussed the barrier faced by minority owned supplier during SD activities. The barriers related to supplier practices included undercapitalization problem, long lead-times for quality correction and lack in qualified engineering and managerial personnel. The study also found that several other barriers which were related to communication, power dependence, profitability, biases, customer firm's effectiveness and second tiering. The study of Wagner and Fillis (2005) reported that small suppliers often faced difficulties in maintaining the standard of advance procuring system of buying firm. The study also highlighted that the small supplier also faces the issues of trust building and power balance during supplier development. The lack of communication and objective misalignment also led to inefficiencies during supplier development activities (Williams, 2007; Humphreys et al., 2011).

### **SCOPE OF THE STUDY**

The scope of this study is to find out the current level of local supplier development practices undertaken by local as well as multinational companies. This study also is focused to explore and list down the supplier development activities and the facilitators required to perform



such activities. At the end, this study also explores and understands the challenges and the issues faced by local and international companies while doing local supplier development and barriers in supplier development. The differences across different industries would be addressed in the subsequent research studies.

## **METHODOLOGY**

This study is the part of a research project with the aim to find out the current state of supplier development efforts in emerging economies, to study the best practices and issue regarding supplier development undertaken by the local industry in developing countries of Asia, to understand the difference between western perspective and eastern perspective regarding supplier development, and then to document it, so that international and local industry can get benefit while doing supplier development activities. The broader study is undertaken by the Center for Operations and Supply Chain Research at University of Central Punjab and would cover motives issues and barriers in supplier development initiatives across different industries. To conduct this diverse research on supplier development convenience sampling was carried out and various companies in all industries are selected. The present study comprises the case study analysis of companies in both manufacturing and service sector, to include organization from various industries.

The nature of this study is exploratory, with the focus of exploring and understanding the current level of supplier development through semi-structured interviews. Systemic combining method is used, which evolves the simultaneous development of empirical research, theoretical framework and case study analysis (Dubois and Gadde, 2002). In empirical research case study analysis has its unique strength in developing new concepts and theories especially in unfamiliar situations or in expanding and exploring the developed theories (McCutcheon and Meredith, 1993). The literature review on supplier development was used to develop the research protocol to conduct the semi-structured interviews. The people interviewed represent a variety of managerial positions having ample knowledge regarding supplier development initiatives and related issues, such as Director, General Manager Production and Supply Chain Manager. Data was gathered during the site visits and detailed research notes were written. General information about the history and introduction of company was gathered from the official website of the companies.

## **CASE BRIEF**

Due to confidentiality, the names of companies are replaced with generic industry names. Pharmaceutical company is considered category leader in Pakistan, with state of the art setup for manufacturing products such as eye drops, tablets and other pharmaceutical products, with an annual turnover of over PKR 1 billion. The "Eye drops" category is considered as its strength and has a major portion in company's profitability; hence increases the relative importance. For this study, the supplier development activities with its three supplier of plastics bottle (used in eye drop product line) were investigated.

Electronics Company is the leading home appliance brand in the country and producer of electrical products targeting to local market. It has come up with a wide range of quality electrical and home appliances/equipment, with annual turnover of more than 1 billion (PKR). The home appliances category is the major source of brand recognition for company which has contributed in majority of its profitability. For the purpose of this case study, home appliances category was selected and the supplier development activities with its two suppliers providing crucial material GPPS (General Purpose Polystyrene) and thermo sole was studied.

Beverages company is an international firm that has been operating in Pakistan for the last many decades. The company formulates the concentrate and sends it over to the bottling plants across the country. For the purpose of this study, supplier development activities with its two supplier providing plastic jerry cans was studied.

Shoe Company is an emerging local shoe-wear brand with the network of almost 100 retail outlets across the country. It also deals in bags and accessories. It has the network of over 200 local and international suppliers in its supply base. In case of Shoe Company, the whole network of shoe suppliers was selected.

FMCG Company, one of the most popular brands in the Fast Moving Consumer Goods (FMCG) industry, is the pioneer in the dairy industry in Pakistan which started its operations working with only 26,000 farmers in 1988. By 2012, it had been able to increase the supplier base and worked with 200,000 farmers, while the milk collection had reached 15,000 tons per day. In case of FMCG Company the network of Milk farmers was selected.

## **CROSS-CASE ANALYSIS**

### **MOTIVES OF SUPPLIER DEVELOPMENT**

Based on the literature review, we identified two motives of supply development: Reactive and Proactive approach. In the sample, except for the Pharmaceutical Company, the reactive approach is frequently indicated as the main motivation for supplier development. In the case of Pharmaceutical Company, the firm faced a lot of difficulties in procuring the plastic bottles (for its eye drop product line) locally. Although, the company was easily importing bottles from international suppliers, but the top management proactively decided to develop the local supplier to protect its self from any potential disruption. For this purpose, the company selected a potential supplier and shared human resources in developing the processes. For example, to detect the defects in the plastic bottle, Pharmaceutical Company introduced the laser technology and shared this technology with its supplier. The supplier also took the knowledge sharing very positively and invested heavily to install this technology. Pharmaceutical company provided the technical help to make the process institutionalized. On the other hand, all companies on the sample used the supplier development as reactive strategy. Most companies involved in supplier development in the reaction of any disruption in the supply. For example, Electronics and Beverages companies switched to local procurement in the response of increasing tariff and non-tariff barrier in the country. The main reason behind procuring from local supplier was to get the cost and time advantages.

## **ACTIVITIES**

### **Capital investment**

Capital investment is considered as the advanced form of supplier development activity in the industry. According to the Table 1, two companies in the sample were investing capital in their suppliers. By this activity, suppliers feel that the buying company owns the initiative and looks at the development activities as its own responsibility and as a result suppliers have a sense of commitment towards their buyers. For instance, Pharmaceutical Company was willing to increase technical and operational capability of its suppliers by investing finances. FMCG Company, the dairy leader in the country, also helped its farmers to develop up dated dairy infrastructure like sheds, silage and milking machines. All of this development cost was invested by FMCG Company in shape of soft loans.

### **Sharing of cost**

As indicated in Table 1, except Shoe Company, almost all the companies shared the cost only with their strategic suppliers. Electronics Company, for instance, shared cost of its local suppliers to enhance the quality of material up to the level of imported quality and once the

quality was up to the mark, it shifted to local procurement. Similarly one supplier of the Pharmaceutical Company was facing an issue that the bottles of eye drop had blocked nozzles. Quality control department at Pharmaceutical Company returned those bottles after the samples were inspected. Later, it acquired laser technology and shared it with the supplier to detect this issue. It shared capital and human resources with its suppliers by sending its employees to develop the inspection process using laser technology. It also invested in the supplier to imbed the quality assurance philosophy in their supplier's culture. Similarly in the case of the Beverages Company, the company required its supplier to modify the product design that required investment. It made sure that it would share the cost by compensating the new mold charges in the future orders.

### **Training/education**

Almost all organizations in the sample were giving training and education to their suppliers. For the training purposes, Electronics Company sent its Quality Control personnel to its supplier; they helped suppliers to make their gauges (Measurement tool) more accurate. It also arranged a resource person to help one of its suppliers in decreasing the defects in insulating material (used in refrigerator). In the case of the Shoe Company, it helped the suppliers in difficult circumstances by sending its team to its suppliers that gave suggestions and recommendations to improve supplier performance. Additionally, training programs were scheduled for process improvement at suppliers. Similarly the FMCG Company started many projects to develop and educate the farmers. The first project was "imported cow project" in which the company imported the cows and distributed those to different farmers. In addition the company had set up the two farms with 120 cows, where the farmers were trained for calf care, clean working conditions and cattle management. These training programs were designed for weekly to monthly time periods.

### **Contracts**

All companies in our sample were having contracts or promising future benefits only to their strategic suppliers. For instance, the Beverage company contracted with one of its suppliers for future business which helped the relationship move forward, but in case of a small supplier (compared to the Company's size); there was no clear commitment or contract for future benefits, which ultimately resulted in the jeopardizing the trust and relationship (Refer to case 6 in Table 1). Likewise, Pharmaceutical Company also reported a similar problem. The company contracted for future business/benefit only with its strategic supplier clearly, but in the case of small suppliers (Refer to case 2 and 3 in table 1) the supplier development efforts did not prove successful as there was no written document mentioning the terms and conditions. The FMCG Company had also an unwritten policy for its farmers that they would get the orders until the farmers refuse to give whole milk production to this company. In this way, it kept its farmers retained.

### **Standardized supplier evaluation program**

The whole sample of this study had standardized supplier evaluation program. For instance, Pharmaceutical Company had developed its suppliers by continuously evaluating the performance and making standards for suppliers to meet. Similarly, a standardized procedure was followed by Electronics Company for all of its suppliers for the evaluation. For example, Electronics Company set standard for suppliers to enhance the quality up to the imported products' quality. The Beverage company's suppliers were required to undertake third party audits following international standard. On the other hand, the FMCG Company did not have a proper evaluation program but indirectly, with the increased milk yield and health of cattle, it could analyze the performance of its farmers.

### **Site visits**

Every organization in the sample was sending its teams and personnel to its strategic and valuable suppliers. Employees of Pharmaceutical Company made visits to its suppliers. The main purpose of the visits was to make sure that the suppliers do not feel alone in development process. Electronics Company also sent its employees to its suppliers. The site visits were very much helpful for increasing overall performance of the suppliers. For Beverages Company, extensive site visits were done for all of its strategic suppliers and that helped companies to conform to international audit standards. Shoe company also conducted surprise visits at its suppliers facilities in order to know if there were any flaws and problems faced by its suppliers.

### **BARRIERS**

#### **Communication barriers**

Pharmaceutical and FMCG companies faced communication barriers while dealing with their suppliers. When Pharmaceutical company offered assistance in developing the technical capability to one of its suppliers, the supplier became offensive and thought as if Pharmaceutical Company wanted to take over its operations. This clearly showed that Pharmaceutical Company had communication barriers with this supplier. Also, when FMCG Company started to educate its farmers, they were unwilling to quit the old practices as they were afraid to use "foreign" practices. This was again a challenge for FMCG Company to create awareness among its farmers.

#### **Lack of trust**

According to the literature, small suppliers face hurdles of trusting bigger firms as far as Supplier Development is concerned. They lack trust because of the fear of losing their business to the bigger firm. Except for the Shoe Company, every other organization faced this issue with some of its suppliers. One of the Suppliers had little trust on Pharmaceutical Company, the fear that Pharmaceutical Company would take advantage of its small scale and would take over its operations did not allow the company to develop the trust. In the case of the Electronics Company, one of its suppliers tried to increase the price, up to the level of import alternatives, once the prototypes were approved and the company had to use its bargaining power to restrain the supplier from price increase. Pharmaceutical company had also concerns about lack of trust, so it backed itself by the contract and restrained this supplier from raising the prices.

#### **Supplier lacking financial strength**

Pharmaceutical and FMCG companies faced this issue among their suppliers. Pharmaceutical company found that one supplier which was of very small scale and lacked resources to invest in upgrading their technology. Similarly the suppliers of the FMCG Company lacked in having a proper infrastructure and facilities such as clean water and sheds. This was a hindrance to increase milk yield. FMCG Company has supported its farmers to build the facilities and infrastructure by investing and educating the farmers.

#### **Supplier lacking technical knowledge**

Almost every company in the sample faced the problem of lacking technical knowledge among their suppliers. One of the suppliers of Pharmaceutical Company lagged behind in technical skills and knowledge. In order to help the supplier improve the technical knowledge, it assisted this supplier. One supplier of Electronics Company also lacked in technical capabilities and it aided this supplier in enhancing process and implementing quality control procedures. One supplier of Beverages Company lacked in technological skills and expertise to work with international buyer and as a result failed to pass the first audit. For the FMCG Company, it was a challenge that the farmers in Pakistan had lack of experience and awareness to handle and manage cattle. Along with that, the suppliers were

unwilling to change their practices as they were following the same practices their ancestors had followed for centuries. In order to cater to this problem FMCG Company started many training and awareness modules for its farmers.

The following table summarizes the data in a way that the columns represent individual cases while the rows represent the motives, activities, barriers and the outcomes. The frequency column highlights the frequency of a particular activity among the sample cases.

<b>SUPPLIER DEVELOPMENT ACTIVITIES</b>										
	Usage	<b>Pharmaceutical</b>			<b>Electronics</b>		<b>Beverages</b>		<b>Shoe</b>	<b>FMCG</b>
Case		1	2	3	4	5	6	7	8	9
<b>Motives</b>										
Reactive Approach	7/9	✓			✓	✓	✓	✓	✓	✓
Strategic Approach	3/9	✓	✓	✓						
<b>Activities</b>										
Capital Investment	2/9			✓						✓
Sharing of cost	5/9	✓	✓		✓			✓		✓
Training/education	7/9	✓	✓	✓		✓		✓	✓	✓
Contract	4/9	✓				✓		✓	✓	✓
Promise of future benefits	4/9	✓				✓		✓	✓	✓
Standardize Supplier evaluation program	8/9	✓	✓		✓	✓	✓	✓	✓	✓
Site visits	9/9	✓	✓	✓	✓	✓	✓	✓	✓	✓
<b>Barriers</b>										
Communication barriers	2/9			✓						✓
Relative power of buyer			High	High				High	High	High
Lack of trust	4/9			✓	✓		✓			✓
Supplier lacking financial strength	2/9			✓						✓
Supplier lacking technical knowledge	4/9		✓			✓		✓		✓
<b>Buyer's perception of outcome</b>		+	-	-	-	+	-	+	+	+
<b>Moved to a pricing mechanism later</b>					✓		✓			

**Table 1: supplier development activities grid**

### Conclusion

The supplier development cases in this study capture the state of supplier development activities in an emerging economy. Based on the cases covered in this study, a few themes are emerging. Firstly the activities such as supplier visits, inviting suppliers to observe the process at buyers' location and having a supplier evaluation procedure in place have been observed across the board, pointing to the imperative nature of these activities in supplier development initiatives. Moreover, the importance of having a sound contract in place addresses the issue of exploitation for both side and ensures smooth working of relationship.

In case 3 and case 7, the spelling out of contracts at the outset was cited as a major reason of the success. Whereas as in case 2, lack of a proper contract made the initiative unsuccessful even after the product was improved successfully. Similarly in case 4 and 6, absence of contracts nearly brought the relationships to a halt. Moreover, clearly mentioning the future prospects of the business also helps in keeping the supplier focused towards the efforts and relationship.

The future direction of this study has several dimensions as multiple examples across different industries are yet to be gathered to assess whether there are certain industry specific phenomena and the reasons for the differences in supplier development practices. Furthermore, the research can be directed to highlight the barriers not only across industries but in the economy as a whole.

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# LOGISTICS RESEARCH IN ASIA: A COLLABORATION NETWORK ANALYSIS

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## ABSTRACT

This exploratory paper is the first work to discuss the current state of logistics research in Asia by investigating the research agenda and collaboration in Asia-based logistics knowledge. We apply research collaboration network analysis to categorize the different research themes, and challenges and collaboration among scholars over a decade (2003-2012) of articles in six peer-reviewed journals. Our findings suggest that there is a number of pivot scholars who are instrumental in research collaboration and building a body of knowledge on Asia-based logistics management at several levels: functional, firm, dyadic, chain, and the network. Though the analysis is restricted to 220 articles found in only six journals, we hope that this paper can shed some light on the research needs from different perspectives and facilitate the progress of logistics research in Asia.

**Keywords:** Logistics Management Research, Network Analysis, Asia.

## 1. INTRODUCTION

Emerging markets and developing economies, especially in Asia, have experienced relatively strong economic growth, estimated at 6.6 and 6.4 percent for 2011 and 2012, respectively, and attracting more financial flows (World Economic Forum, 2012). This increase is paralleled in the logistics industry, an important driver for trade and industry. Overall, the global logistics market is valued at US\$3.5 trillion, and is expected to be US\$4 trillion by 2013. Most of the demand will shift from North America and Europe to the emerging economies in Asia. Its share of the global market is currently 18% and this is expected to rise to 21% by 2013 (Webb, 2010).

In another recent report, 11 Asian countries are reportedly in the top 30 in the Global Competiveness Report 2012-2013 (World Economic Forum, 2013). Some of these countries are also high on logistics performance and instrumental in logistics connectivity. Indeed, 9 Asian countries rank in the top 30 in the recent Logistics Performance Index 2012 (Arvis et al., 2012). However, Soni and Kodali (2011) have indicated that Asian countries now contribute nearly 10% of research studies which is more than the findings of Sachan and Datta (2005) (6.1%). Clearly, there seems to be a sustained interest in this field of study, which serves the purpose and intent of this paper. Therefore, this study aims at assessing the research collaboration relationships between scholars working on logistics and supply chain research in Asia from the perspective of the papers published in the logistics and supply chain journals.

## 2. LITERATURE REVIEW

Several pieces of work have been written on logistics research in Asia. Given the complexity of supply chain issues even in a research context, it is understandable that research collaboration is needed to meet publication outcomes. Research collaboration as a sub-domain of interest is not new. Melin and Persson (1996) have studied the effects of scientific collaboration and suggest that the tremendous growth of such collaborations is attributed to the internal dynamics of the subject matter and the prevailing environment. Logistics management, which straddles several traditional learned disciplines, is one such subject matter. Indeed, research collaboration is intense and fast becoming a requisite for success in the publication arena which often requires multi-disciplinary expertise. According to Melin



and Persson (1996), a key indicator for the success of such collaborations is the extent of co-authorship in scholarly works. An obvious outcome of collaboration is the improvement in scientific productivity (Lee & Bozeman, 2005). On the other hand, the literature has also highlighted the collaboration paradox and the problems of research undertaken in developing areas such as for logistics in Asia (Duque et al., 2005). The literature is also replete with theoretical lenses such as the resource based view, and transaction cost theory which have been used to show that international research collaborations are more successful when complementary resources are increased and transaction costs reduced (Ou et al., 2012). Clearly, social networks is a key mechanism here. However, the works so far do not examine the extent of collaboration among logistics management researchers working in this domain particularly in an Asian context, which is the purpose of the focus of our paper.

### 3. METHODOLOGY

As this paper focuses on studying research collaboration from scholarly peer reviewed journals pertinent to logistics and supply chain management, we target the SSCI/ SCI ranked journals. Also, as the study's scope is limited to Asia, a large geography, we rely on a realistic working definition for Asia. Drawing from the Central Intelligence Agency (2013) report, Asia is divided into 56 countries, with Russia and Turkey having part of their land in Europe. We chose six journals: the International Journal of Logistics Management (IJLM), International Journal of Physical Distribution & Logistics Management (IJPDLM), Journal of Business Logistics (JBL), Journal of Supply Chain Management (JSCM), Supply Chain Management: An International Journal (SCMIJ), and Transportation Research Part E: Logistics and Transportation Review (TRE). This yielded 2,288 papers for potential analysis. In terms of the data collection, Figure 1 details the necessary steps. Finally, choosing only those papers that focus only on Asia and not those that compare Asia with the other regions, led to 220 data points for actual analysis (Table I). Table II presents the breakdown by journal title for our period of analysis, 2003-2012.

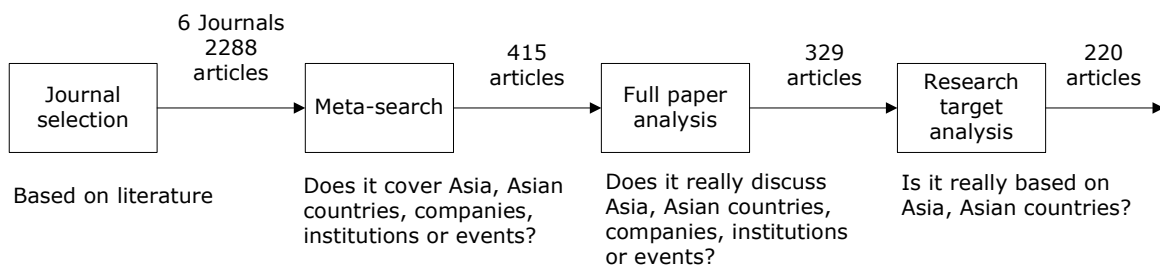


Figure 1: Screening methodology

Table I. Downloaded articles for research analysis

Journal	Year to date	Total	Download (%)	Composite (%)	Final (%)
IJLM	2003-2012	188	29(15)	17(9)	7(4)
IJPDLM	2003-2012	423	74(17)	56(13)	33(8)
JBL	2003-2012	210	18(9)	16(8)	7(3)
JSCM	2003-2012	447	30(7)	22(5)	7(2)
SCMIJ	2003-2012	446	111(25)	86(19)	68(15)
TRE	2003-2012	574	153(27)	132(23)	98(17)
Total		2288	415(18)	329(14)	220(10)

Note: Composite refers to papers that include comparing Asia with the other regions.

Table II. Output of Asia-based articles by journal title (2003-2012)

Year	IJLM(%)	IJPDLM(%)	JBL(%)	JSCM(%)	SCMIJ(%)	TRE(%)	Total(%)
2003	-	5(15)	1(14)	-	5(7)	4(4)	15(7)

2004	-	1(3)	1(14)	-	4(6)	5(5)	10(5)
2005	-	3(9)	-	-	8(12)	4(4)	15(7)
2006	1(13)	8(24)	-	1(14)	8(12)	7(7)	26(12)
2007	-	1(3)	1(14)	-	6(9)	6(6)	14(6)
2008	-	2(6)	-	3(43)	12(18)	15(15)	32(15)
2009	2(29)	4(12)	3(43)	-	9(13)	10(10)	28(13)
2010	-	4(12)	1(14)	-	4(6)	10(10)	19(8)
2011	2(29)	4(12)	-	1(14)	7(10)	24(24)	38(17)
2012	2(29)	1(3)	-	2(29)	5(7)	13(13)	23(10)
Total	7(100)	33(100)	7(100)	7(100)	68(100)	98(100)	220(100)

We then used our data, less the 38 single-authored papers, to construct a research collaboration network showing who is collaborating with whom, using the software NodeXL. A node depicts an author and a tie represents co-authorship on a publication. We normalized the size of a node by the number of papers that the author had published.

Table III shows the classification technique used for the research collaboration network analysis in this paper where we have classified our research fieldwork based on the following: background of paper (author, year, institution), level of analysis (firm, dyad), hypothesis formulations, research design, research methods (survey), data analysis techniques (SEM, path analysis, t-tests), theory (resource dependency, institutional theory, TAM), Industry (manufacturing, services), and subject area (research topic).

Table III. Classification framework for research analysis of the papers

Classification	Categories	References
Background	Year published, Social network of authors in Asia, number of authors, author institution, region covered by the articles	Sachan and Datta (2005); Gubi et al. (2003)
Level of analysis	Function, Firm, Dyad, Chain, Network	Selviaridis and Spring (2007)
Hypothesis	Specific statement of predictions	Sachan and Datta (2005)
Research design	Based on empirical work or desk research	Gubi et al. (2003); Sachan and Datta (2005)
Research method	Conceptual work, survey, math modelling, interviews, case studies and others	Woo et al. (2011);
Data analysis techniques	Data analysis techniques show how researchers have addressed problem	Woo et al. (2011);
Theory	Theoretical perspectives applied to articles	Shook et al. (2009)
Industry	Sample industry of the articles	
Subject area	Research focus of the articles	Stock and Broadus (2006)

#### 4. RESULTS AND DISCUSSIONS

The research collaboration network analysis of Figure 2 is based on 182 co-authored articles involving 448 authors.



Figure 2: Research network analysis for community based on Asia

Note: Node = individual author. Size of node = normalized by the number of publications published by an author. Tie = co-authorship of a publication.

Thus far, from Table IV, there exists evidence of research collaboration among the authors as indicated by the density of the network shown in Figure 2. However, what is more pertinent is that single authorships are a minority and the number of publications has the potential to increase, given the inclination to collaborate. This resonates well with Melin and Persson (1996). Moreover, as shown by Table V, the modal tie of the co-authored papers is 3 which signals an optimal density for research collaboration, presumably pointing to greater productivity through the power of 3 in publication outcomes. Some of the universities providing the guidance and encouragement in that direction are from Asia itself, as suggested by Table VI. This augurs well for logistics research in Asia as Asian based institutions are taking the lead in growing the necessary body of knowledge. This also attests to an institutional environment that fosters international and regional collaboration between these schools. However, the extensiveness of this collaboration decreases markedly after 4 co-authors. This findings could be viewed through the lens of Duque et al. (2005)'s collaboration paradox. We have unearthed another variant of the collaboration paradox. This perhaps indicates a point of diminishing contribution from the authors, or what is proverbially known as the case of too many cooks spoil the broth. Therein lies the challenge of multi-partner research collaborations, past and present.

Next, Table VII, reveals that the research collaboration and the research agenda on logistics management so far has focused on Northeast Asia, which comprises Taiwan, China, Hong Kong, and Korea. This concurs with the prevailing interest from academia and practice on China as a manufacturing hub and the associated logistics challenges and opportunities. On the level of analysis, we observe that most of the research activity is focused at the firm level with very little done at a dyadic level. This is interesting as research in the other domains have since moved to a dyadic discourse (Table VIII). At the same time, Table IX suggests that most of the papers studied in this manuscript are not empirically driven nor have a rigorous conceptual or research model formulated. This hints at the choice of academic postulations as an emerging area of work. Collaboration is typically required and

beneficial when conducting research in environments that require local inputs and contacts (e.g. translation and fieldwork) or when local governments dictate the partnership with a local researcher. In Asia, both considerations are needed given the level of political uncertainty and the diversity of languages and customs. On the approach taken by research design, our results in Table X support the findings of Table IX in that the current state of work on logistics research in Asia are largely quantitative and survey based (see also Table XI). Most of the survey based works are constructed on an established theoretical lens as shown by Table XII though the analysis are at best at the intermediate statistical level only. In this regard, the resource based view is the most popular and amenable for logistics research in Asia (Table XIII).

On the industry being studied, our results suggest that manufacturing and logistics remain high and most studied on the researcher's agenda of theory building and knowledge advancement (Table XIV). This correlates well with the findings of Table VII, which hints at a focal research on China. Finally, from Table XV, it is interesting to note that while research on logistics management in Asia has traditionally been studied on logistics or supply chain collaboration between firms operating in this part of the world, a new stream of logistics research is emerging. Table XV rightly suggests that sustainable or green logistics, especially the empirical work related to this area has been receiving greater academic attention more recently.

## **5. CONCLUSION**

This paper has attempted to investigate the extent of logistics research in Asia. In particular, this paper has also studied the level of research collaboration between scholars working on logistics / supply chain management in Asia, through an application of social network analysis. We have rebranded this analysis as research collaboration network analysis and find that there are pivotal scholars who are critical to growing the research network and for building a body of knowledge on Asia-based logistics management at several levels: functional, firm, dyadic, chain, and the network. Greater collaboration is needed between Asian scholars working in this domain. There are several limitations to this study. First, the choice of journals is restricted to only those popular in the domain. Second, we relied on only 6 journals. Thus far, the literature has not set a minimum number of journals needed for sufficient analysis saturation. Notwithstanding this restriction of 220 articles and 6 journals, we hope that this paper can shed some light on the research needs from different perspectives and facilitate the progress of logistics management research in Asia. Perhaps it is time to consider embracing new marketplace tools such as Join.Me.

**Note:** Tables IV – XV have been removed from the conference paper. They are available from the authors upon request. Yen-Chun Jim Wu is the corresponding author and can be reached at wuyenchun@gmail.com.

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# IMPROVING THE UNDERSTANDING OF ON SUPPLY CHAIN INTERACTION AMONG POST GRADUATE STUDENTS THROUGH THE APPLICATION OF A BUSINESS GAME-A PILOT STUDY

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## ABSTRACT

Supply chain management is an educational topic throughout several business and engineering schools. However, most courses focus more on research findings than on actual practical experience, which leads to an educational gap. Students gain theoretical knowledge, but hardly apply it during their studies. In order to overcome this separation, game-based learning is to some extent implemented in curricula, either as a supporting activity or as individual courses. Games offer students the opportunity to experiment in a safe environment in order to gain knowledge that can be transferred later to the real world. In business and engineering education, serious games are mostly played in a workshop setting. This paper compares two different game-based learning set ups with students using the same game. The aim is to gain more insight in how the workshop set-up influences the learning outcome of a *serious game*.

## 1. INTRODUCTION

Although globalisation of manufacturing has offered significant gains on both the company and the Supply Chain (SC) level, it has made competition stiffer for each involved player and for the chain as a whole. In addition, a number of behavioral factors make the challenges, which the organization faces, even greater. First, the bounded rationality of the economic actors (Simon, 1997) is just a supplemental element, which exacerbates the situation. Decision makers generally opt for the first satisfying solution, and hence, they stop looking for better alternatives according to the bounded rationality principle. Second, decision makers, like people in general, are prone to the misperceptions of feedback. This means that their performance in complex and dynamic systems is hindered by nonlinearities, time delays and feedback structures (Serman, 1989). Subsequently, decision makers may make low-value decisions. Third, decision making in dynamic systems is hard because it calls, respectively, for dynamic decision making, that is, a stream of decisions closely depending on one another.

Dynamic systems such as SC compel their workforce to be faced with ever-changing working environments (Baalsrud Hauge et al., 2006). This stresses the need of continuous learning, which constitutes the true competitive advantage for organizations (Senge, 1990, p. 17). The complexity makes it difficult to predict the impact of decisions taken, thus future SC managers need to be trained in taking decisions under uncertainty and to reflect on how

these decisions impact the whole SC (Manuj, 2011). This type of practical decision making is necessary to take shape within the business and engineering schools since it prepares future practitioners for the requirements set within each industry, typically in the form of increased competition leading to more complex and vulnerable SCs. Although, taking into consideration these requirements, the educational time should not increase. The aim should be to enrich the relevant academic programmes so that the students acquire skills on how to apply methods and approaches in a dynamic environment, and learn to observe, reflect and then take decisions. Within business and engineering schools there is debate about linking research results and practice, with the higher education focusing mainly on transferring research outcomes rather than on practical skills based on experience (e.g. Starkey and Tempest, 2005).

## **2. BACKGROUND**

Game based learning, i.e. the use of games to support learning process (Breuer and Bente, 2010), has a long tradition as a teaching method (Faria et al., 2009) and is today used at several business and engineering schools. Serious games have been defined as entertaining games with non-entertainment goals (Serious Game Initiative, 2002; Raybourn, 2007). They are games that educate, train and inform (Michael & Chen, 2006). The advantages of Game-based Learning (GBL) have been addressed by several authors (Killi, 2005; Alkanak and Azami, 2011; Razak, 2012; Riedel, 2011; Amory, 2007; Prensky, 2006; Quinn, 2005), since they have been demonstrated to provoke active learner involvement through exploration, experimentation, competition and co-operation. They also address the changing competences needed in the information age: self-regulation, information skills, networked cooperation, and problem solving strategies, critical thinking and creativity. Semini (2006) also pointed out the games can be seen as an extension of simulations. However he also addressed that games are more suitable than simulations to teach decision making in SCs, due to the explorative environment. However, many of the used games are not publicly available, being in-house developments, and there have been propositions about which games can be used for SCM education. For instance, in the late 1990s Campbell (1999) suggested 8 suitable games, and in 2007 Lewis and Maylor (2007) suggested a list with 10 different games. The most famous one is still the Beer Game explaining the bullwhip effect. The underlying learning theory for most games used for SC management is constructivism, where knowledge is created at an individual experience and thus different for each participant.

In the field of business and engineering education, serious games are mostly used in a workshop setting (Angehrn and Maxwell 2009) and either Kolb's experimental learning cycle (Kolb, 1984) or Nonaka's SECI (Nonaka, 2000) model is used for the implementation of a game in a course. The games seek to enhance the learning motivation as well as to simulate real enterprises (Popescu et al., 2012). Most of the SC games are facilitated, i.e. the debriefing is not within the game, but outside the game (Luccini, 2012). The learning outcome is therefore not only dependent on the game itself, but also on the facilitators' ability, and the learning results are not only based on the game, but on the course setting. In such situation it can be difficult to prove the effectiveness of a game, which is prerequisite for higher implementation rate. We have therefore compared the learning outcome, using post-game questionnaire with a Likert scale (range 1 to 7, 4 being neutral) and used it for the same game in two different settings.

### **3. Design and experimental set-up**

#### **3.1 Game description**

The game *Seconds*, developed at the University of Bremen, is used to train students in SC-related decision making. It is a facilitated, collaborative multi-player online game. The gaming environment aims at increasing the awareness of how a participant's own decision making impacts on the SC. The game creates a safe learning environment in which the students can apply different SCM strategies and discover the impact of their decisions on the system. The goal is adaptable (depending on course setting), but mostly it aimed at producing a specific product in cooperation with other players in order to meet customer's demand and deliver the goods in the right quality and quantity at the right place and the right time, taking all costs and expenditures into account. No player is allowed to produce finished goods on his/her own, and therefore the number of parallel running processes for each participant is limited (the facilitator can decide the number). A simplified accounting system is implemented, i.e. the game informs on several performance indicators that are used for the analysis and calculation. It is configurable, and the level depends on the knowledge level of the players (pre-configured). The students also have to negotiate with their potential suppliers and customers in a dynamic competitive environment, where apart from price, they also have to consider issues of availability, quality, logistics costs, as well as long term relationships. The entities 'process' and 'resource' constitute the model's most important objects. Typically, the process function transforms the resources to produce outputs/products. The user can configure the resources based on the contribution of a resource to a process.

In the simulation model a process is used to transform input materials into output materials. The duration of a process is given by a predetermined value which is multiplied by a site factor. The site factor, however, depends on the process category and a corresponding site attribute. For transport processes the game designer can also define a route. By doing this, it is possible to constrain the execution of certain processes to certain sites, while the output site of the process is defined during runtime by the player. Input materials show a different behaviour depending on their type like consumables and durables as well as tangible or intangible. These can be, for instance, knowledge or permissions, which are necessary to execute a process, but are neither occupied nor do they vanish after completion (Hüther, 1996).

The main task was to develop, manufacture and also sell a car (the actual end-product of the SC) built in collaboration on a global SC. Each team should compete on income and costs, yet consider the long term strategic implications of their membership in a SC. The product consisted of several components (e.g. chemicals, steel, rubber) produced by different stakeholders to create a competitive environment among the players. Using the game *Seconds* the scenario included car retailers, as well as companies that produced car bodies, tires, glass, plastic, steel, textiles etc., covering the whole range of parts and components that would be required to manufacture the final product, namely cars. Nevertheless, admittedly the SC created in the scenario was one with reduced complexity compared to reality.

#### **3.2 Course integration**

The University of Bremen, faculty of production has long experience in GBL, and offers its students several courses in which a game is a vital part of the curriculum. Due to the changes in the skills students need to have for working in a dynamic environment, the first curriculum for training strategic decision making using games was developed for the winter-term 2005-2006. It is designed for the second year of the MSc on System Engineering, Industrial Engineering and Production Engineering. The prior knowledge of students on



decision making and SCM vary. Consequently, the curriculum promotes a blended learning concept in which the lecturer both mediates the theoretical skills, and works as a facilitator during the gaming sessions. The workshop in which the game is used is based on Kolb's learning cycle (Kolb, 1984), and has been subject to several revisions in order to reach the learning objective. Seconds was developed in order to replace a previous game that proved to be too complicated and time consuming to use, and has been in use since 2007. It is specifically developed to support the learning goals defined in the curriculum. At the moment it is one of two games used as part of a lab course on "Decision making in distributed production environment". The part using Seconds comprises of 6 units - one for introduction to the basics of SCM and a tutorial on the gaming environment and five for playing. Methods for strategic decision making are successively introduced into the course and the students have to apply at least six of the methods during the course. Each session lasts 5 hours. The play time is 3-3.5 hours for each session and at least 30-45' for debriefing and reflection. At the end, each student does also have to present and deliver a detailed analysis of the game play and his/her role.

The students receive a role and a starting scenario including necessary business information, so that they are able to develop a strategy for their company. The gaming scenario evolves as the players play the game. Depending on production volume and time, the player can gain experience and skills needed for producing higher quality. Only headquarter and a company description including current products is available at the beginning, i.e. there are no production sites, running processes etc. implemented in the gaming scenario (see Figure 1). This allows the students a high degree of freedom in making the relevant decisions.



Figure 5: GUI<sup>1</sup> showing country specific information needed for deciding where to establish sites

Seconds has also been used for the last couple of years at the Nottingham University Business School, as a supplementary workshop to a postgraduate course on SCM. Therefore, during the gaming workshop there is no introduction to strategic decision making in SCM or in the basics of SCM, since this is well known in advance. In addition, the workshop setting includes a very brief introduction to the game and much shorter playing time. The students each year had two playing sessions of 2.5 hours with an additional 30 minutes for debriefing. This has some implications for the gaming scenario, as the facilitator(s) has set-up the scenario in advance, including the first production sites and the first production processes, so that the students can start to play when the game commences. This is necessary because it is not enough time to let the game evolve, especially since the students need different amount of time in order to take decision on the location of their new sites, production processes, or to change production strategy; i.e. the degree of freedom for taking decisions initially on production sites was lower than in the Bremen case.

<sup>1</sup> GUI refers to Graphical User Interface

The evaluation of the learning outcome in the game is done by collecting feedback from the students directly after playing, as well as by using a questionnaire. For the Bremen case we also have laboratory reports describing the process in more detail. Based on the observation of the groups, it is expected that the learning experience of the class with only two sessions and a short time for playing should be lower than the one with more sessions. The time to reflect and to apply the methods is shorter, and it is also expected that the stress level will be higher. The next section provides the analysis of the questionnaires.

#### **4. Comparative analysis**

The first observation is that the UK students have more company experience, as well as experience with computer games, but are less used to GBL. The Bremen sample comprises of 70 students (over 3 years), and the UK of 36 students (over 2 Years).

Regarding the Bremen case, a key issue is that 76% of the students knew each other before starting with the game. This might have influenced the high number of team members that were satisfied with the teamwork (83% was better than neutral). Only two participants disagreed with the statement that the team was working well and 89% were motivated as they started from the beginning, while only three were less motivated. This might influence the outcome, but is a key issue for using games. The students found their task clearly structured and also the gaming environment (both 83% rated 5-7). This may have helped the students in focusing on their task in developing a strategy to follow just from the beginning and to initialise the operation by installing the production processes. To transfer the experiences gained in the game to the reality, it is important that the students recognise similarities. In our case, 91% thought that the given scenario was realistic and matched their previous internship experience. Considering the questions on whether the game helped them to understand theory, 93% agreed upon this, and also 93% said it helped in applying strategic thinking and theory. Important for the achievements of learning goals was to assess if the student took decisions. The percentage of people not taking the decisions intuitively was very high (94%), but interestingly while most students gave the highest score on the Likert scale for taking decisions (7), for using a structured approach most of them rated it at 5. This indicates a need for improvement. Finally we assessed their opinions on decisions on SC and cooperation. In the first case, 66% reported a change where as 75 answered the same for understanding of cooperation. 93% reported that they had improved their communication skills. Altogether, it appears that the learning objectives are fulfilled. However, it has to be taken into consideration, that the settings have been continuously adjusted to increase the learning results over the years.

Regarding the Nottingham case, most of the students in the group knew each other and thought that team work worked well. The majority thought that it was important to prepare in advance and the time offered was overall borderline sufficient. During the game the majority felt motivated (80%) and moderately relaxed (only 23% indicated they felt stressed) since it was felt by the participants that they had enough time to carry out the tasks at hand. Although there were no issues with understanding the structure of the game it was felt by 50% of the participants that there was room for improvement in terms of clearly defining the tasks that the group needed to carry out. The vast majority (81%) thought that the game helped them to understand the theoretical content delivered in the course and helped them to increase their awareness of impact of their own decisions in the supply chain (81%). Similarly, most of the group members had the opportunity to apply what they have learned theoretically (66%) especially in terms of different supply chain strategies (63%) and they felt that the game mirrors the complexity of supply chains to a very large extend.

In the Nottingham case it was felt by most of the participants that the concept of the game sustained their interest throughout and helped them to support the decision making process overall. The majority also demonstrated a marked preference in playing the game in few long sessions rather than in several short periods. As part of the decision making process the participants mostly based their decisions on strategies. The majority felt that they took a lot of decisions that played an important role in the game. Similarly, the majority of the group felt that they were actively participating in cooperation that in turn offered them an impression on supply chain cooperation issues. They felt to a great extent that they had the opportunity to learn something new on supply chain cooperation and further gain insight on the cooperation between different stakeholders and persons. Finally, most candidates felt that the game supported their egoism (77%), which might be attributed to competitive dynamics during the game play session. It was not clear whether the game scenario changed the group's understanding of how decision making impact on the supply chain and also it was not clear whether it would be easy to integrate it in their daily routine. Interestingly most thought that it did change their understanding of cooperation in SC, however, most felt moderately in terms of its impact on their future work. The majority of the participants rated that the game supported learning (64%). Similarly, most of the participants thought that it is designed in such a way that the player learn to cope with time pressure, and uncertainties among other things. Finally, the group felt that the game does support creativity and responsibility (56%) and that it further helps the participants improve on gathering information (75%) and also improving their communication skills (75%).

Seconds is focusing on application of knowledge and the development of decision making skills among students. In order to improve the learning outcome and experience, it is therefore important to better understand the limitation of the experimental set-ups, and see if this can be improved. We have therefore compared the overall learning experience. Comparing the two groups, the group work was much better in the Bremen group. A reason for this can either be that they knew each other better, but also, and that is what we observed, that the group work evolved over time and therefore was better in the group playing longer, since they realised that the success of the game depends on their ability to cooperate. Two other issues are of high relevance – the time constraint and also the stress level. The group with only two sessions and heavily time reductions do mention this as an issue. The Bremen group did not raise similar issues, and indicated a lower stress level. This group also showed a better understanding of their task, and reported in general that they could well apply their knowledge.

Considering the topics for which we intend to train the students with Seconds, i.e. strategic decision making in supply chains, we also recognise a difference between the two groups. The group in Bremen reports that to a higher degree they take decisions during the game. A main reason for that is however, that they are forced to take decisions in order to establish their production, whereas the Nottingham group can produce right from the start. Comparing the two groups in terms of applying strategic decision making, the differences are not so evident; it is around 10% higher for the Bremen group. A key issue is whether the game supports strategic thinking. Regarding this question, the Bremen group does deliver very positive results (93%) compared to the Nottingham group (62.5%). Comparing what the students thought they learned on supply chain, the Bremen group has much higher results. This is probably more a result of the background of the students than depending on the gaming scenario, since the course in Nottingham is mostly with students coming from supply chain management and operational management, whereas the Bremen students are engineers with little previous knowledge on supply chain management.

## **5. FINDINGS AND CONCLUSIONS**

Several authors have concluded that there is a need for GBL in business and engineering education (Faria et al.2009,)), but it is also well known that the penetration rate of games are low. One reason might be that it is difficult to find the right game, to deliver the proof of evidence and that it requires a lot of skills from the teachers. Furthermore, the literature does also mention the aspect of instruction (Bellotti et al., 2010). This is one of the area in which we try to contribute with the comparison of our two groups- to what extent does factors like introduction to the topic and the gaming environment, reflection and playing time (shorter in the Nottingham group than in the Bremen group) influence the learning experience. Our comparison demonstrates that there are difficulties in transferring games developed for a specific setting to other environments and still achieving the same results. Based on the comparison of the two workshop settings, it can be reasoned that the use of specific gaming scenarios can be transferred to be used in different settings, but that changes concerning time used for playing has a large impact on the learning outcome. This is of course not unexpected, but demonstrates the problem of the issues around the use of GBL in the educational context – the games are designed for one setting and hard to change to fit into a different one, without a reduction in learning outcome and learning experience. This comparison shows clearly that there is room for improvement in the experimental set-up in Nottingham. In order to make sure that the difficulties are not associated with the differences in the course setting, it would be necessary to set-up exactly equal experiments in both universities. This is not possible, so based on the feedback of the students and the results; we are now looking at different possibilities. The first action we will undertake is to develop an improved description for online use explaining the different GUIs, the models and the gaming scenario. This will be provided to the students as soon as they register. In addition, we will also prepare an online tutorial, which is typical for several complex entertainment games, so that the students can have a hands-on session before they visit the class. Based on these changes, planned to be implemented before we start the next year teaching session, we will repeat the experiment and compare the two groups again.

Using games as part of the curriculum or as an addition to the existing module structure has been proven to be a useful practice in facilitating the learning process. More specifically, the rewards are focused on engaging with other participants in order to make decisions and also experiencing the impact of these decisions within a dynamic environment. However, based on the two cases discussed, in order for a game to be a rewarding and effective, in terms of their learning targets, experience for all participants certain areas need to be considered closely. For instance, different settings' parameters (scenarios, number of students participating, duration etc) impact in the effectiveness of the game and ultimately on whether the participants will reflect on learning outcomes. With this paper we have demonstrated that a significant part of the preparation, before and during implementation is defining the learning effectiveness parameters of the game. Setting the appropriate conditions in which the game will take place is the aim and not simply its implementation. Our paper suggests that future research should focus on assessing how the same game can have different outcomes based on the same settings, and identify optimum conditions that determine the most effective learning outcomes. Setting an environment in which the dynamic exchanges and decision making can take place will ultimately form the basis for a productive experience.

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