



Risk assessment in multimodal supply chains

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ABSTRACT

Complexity and disintegration are emerging as major challenges in supply-chain risk management. It has become more difficult to identify risks as supply-chain operations have fallen into the hands of outside service providers, and are therefore less visible. The risks, their identification and impact depend on the position of the companies in the chain, and on the level of analysis they can carry out. In this paper we present preliminary research concepts and findings concerning the identification and analysis of risks in multimodal supply chains. Our research approach is holistic, and incorporates perspectives from different parts of the chain. The multimodal maritime supply chain in focus runs from the Gulf of Finland to the Finnish mainland. We map the process and the structure, and present a new framework for categorizing the risks in terms of their driver factors in order to assess the overall impact on the performance of the supply chain. Finally, we analyze the risk impacts in terms of delays in the chain by means of Monte-Carlo-based simulation.

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1. Introduction

Global supply chains are formed by a multitude of companies acting as part of a long and complex logistics system. The continuing disintegration and the specialization of operations have made the chains vulnerable to disturbances coming from both inside and outside the system. The visibility of operations outside the companies' own functions has decreased, and with it the ability to identify risks threatening them and the whole supply chain. Harland et al. (2003) found that less than 50% of the risks were visible to the focal company in the supply chains they examined. The risks that are identified are typically related to the companies' own functions. In most cases, in terms of business impact, risks of disruption are much greater than the operational risks (Tang, 2006). There is therefore a need for a broader view of the supply chain that would facilitate proper risks identification.

Managers selecting a supply-chain-management strategy should first understand the sources of uncertainty and find the way of reducing the level that suits them best (Cucchiella and Gastaldi, 2006). Integrated and seamless logistics can play a crucial role in facilitating global supply-chain processes (Banomyong, 2005). Yet, in practice, greater integration increases dependency between companies and exposes them to more risks (Hallikas et al., 2004). Indeed, the increasing amount of risk in the supply chain is a current focus

of interest in logistics (Minahan, 2005). According to Jüttner (2005), any approach to managing risks from such a perspective must have a broader scope than that of a single organization, and provide insights into how the key processes should operate across at least three organizations. Hence, in assessing supply-chain vulnerabilities companies need to identify the risks not only to their own operations but also to all other entities, as well as those caused by linkages between organizations. A disruption affecting an entity anywhere in the supply chain can have a direct effect on a corporation's ability to continue operations, get finished goods to the market, and provide critical services to customers. For example, a ten-day shutdown of 29 US ports cost the US economy one to two billion dollars per day, which illustrates the effects that such disruptions can have (Park et al., 2008; Jüttner, 2005).

Multimodal container transportation is playing an increasingly important role in global supply chains and trade. Container transportation has expanded significantly over the last 10 years, and the trend shows no sign of slowing down. According to the World Trade Organization, the world's container-shipping capacity tripled in the last decade (World Trade Organization, International Trade Statistics, 2010), which illustrates the significance of multimodal maritime supply chains as part of a global logistics system. Even though there have been several studies on supply-chain risk management, however, very few of them focus on the multimodal maritime supply chain. Given that supply risks, and further the likelihood of disruption, are emerging as a key challenge in supply-chain management, the ability to identify the parts of the chain that are more prone to disruption is becoming a critical first step in managing the frequency and impact of disruptions that may endanger the security of supply (Trkman and McCormack, 2009;

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Singhal et al., 2009). The limited information sharing and collaboration that is typical in the supply chain limit the visibility of risks to some practitioners. There is thus a need to provide a more holistic view by studying the processes involved as an integrated system.

The Gulf of Finland (GoF) is the most important transport route accommodating Finnish cargo flows. Finland's major ports are on its shores, and are in a key position as far as security of supply is concerned. The risks affecting GoF supply chains could have a devastating effect on the downstream organizations, and furthermore endanger Finnish business life and the livelihood of the people. The sources and impacts of the risks should therefore be studied, and that is precisely where the contribution of this paper lies. The aim is to present an assessment of risks and their effects in a multimodal maritime supply chain. A case study was conducted, the purpose of which was to systematically analyze and evaluate the risks affecting a multimodal maritime supply chain between the Gulf of Finland and the Finnish mainland in terms of the nature of their impact. The study is based on literature focusing on risks and supply-chain risk management, and on the findings from interviews. Most of the research was carried out in three overlapping phases. The interviewees were identified and the interviews conducted in the first phase. The risk analysis comprising the second phase involved an expert group of researchers and practitioners in the field. In the final phase, the risk impact of time delay was evaluated by means of simulation in order to obtain a more in-depth perspective on the possible consequences.

The paper continues with a literature review covering the key concepts of supply-chain risk management and multimodality. The following, empirical part of the study begins with a description of the operational area, the study methods, and the process of the case supply chain. The uncertainties are identified and assessed, and a risk analysis follows in which the simulation results illustrate the delay impact of the risks. The conclusions are presented and discussed in the final section.

2. Literature review

Supply chains in the modern world are complicated networks that stretch over longer and longer distances, which makes them vulnerable to a variety of risks. Global supply chains require highly coordinated flows of goods, services, information and money within and across national boundaries (Mentzer et al., 2001). Events affecting one entity or process may interrupt the operations of other members of the chain. Hence, it is important to investigate cross-border supply chains in the selection and implementation of risk-management strategies (Manuj and Mentzer, 2008).

Supply-chain management entails proactive relationship formation and integration among various tiers in the chain (Trkman et al., 2007). Company management should take the supply chain into account in order to construct a holistic understanding about the sources of risks. Jüttner et al. (2003) define supply-chain management as the identification and management of the risks involved through coordinated action among the members in order to reduce vulnerability as a whole. Supply-chain risk management entails identifying the potential sources of risk and implementing appropriate actions to avoid or contain vulnerability. Jüttner et al. (2003) describe vulnerability as exposure to serious disturbance, arising from risks both within and external to the supply chain, and supply-chain vulnerability as the propensity of risk sources and risk drivers to outweigh risk-mitigating strategies, thus causing adverse consequences and jeopardizing the supply chain's ability to effectively serve the end customer. How sensitive a supply chain is to these disturbances is measured in terms of its vulnerability. How vulnerable it is to disturbances

depends on its structural agility and resilience, and in this (risk) management plays a crucial role.

The vulnerability of a supply chain does not assign probability, and it is therefore essential to identify the risks. This is a key activity on which all other aspects of supply-chain risk management are based. In reality, it is virtually impossible to list every conceivable risk, and identification highlights the most significant ones that affect the supply chain. Inter-organizational people usually have the most intimate knowledge of their own organization and its conditions, but not necessarily the capability to identify risks. Organizations cannot rely on personal knowledge and informal procedures, but need more formal arrangements (Waters, 2007).

As many authors acknowledge (i.e., Caridi et al. 2009; Al-Mudimigha et al., 2004), one of the key factors in risk identification is visibility in the supply chain, which is beneficial in terms of efficiency (e.g., Smaros et al., 2003), productivity, and the effective planning of operations (e.g., Petersen et al., 2005). Christopher and Lee (2004) describe visibility as the actors' knowledge of what goes on in other parts of the chain.

The literature on supply-chain management usually defines risk in purely negative terms, and as leading to undesired results or consequences (Harland et al., 2003). A standard formula for the quantitative definition of supply-chain risk is

$$\text{Risk} = P(\text{Loss}) \times I(\text{Loss})$$

where risk is the function of the probability (P) of loss and the significance of its consequences (I) (Manuj and Mentzer, 2008).

Hetland (2003) and Diekmann et al. (1988), on the other hand, view risk as the implication of an uncertain phenomenon. Waters (2007) explains the difference: risk occurs because there is uncertainty about the future, which means that unexpected events may occur. Knight's (1921) distinction between certainty, risk and uncertainty is probably the best known and most used typology of uncertainty for risk management. In his definition of risk Knight coined the terms (quantitative) "measurable" uncertainty and (non-quantitative) "unmeasurable" uncertainty when there is only partial knowledge of outcomes in the form of beliefs and opinions.

Although awareness of supply-chain vulnerability and risk management is increasing among practitioners, the concepts are still in their infancy and there are insufficient conceptual frameworks and empirical findings to give a clear sense of the phenomenon of risk management in global supply chains (Jüttner, 2005; Manuj and Mentzer, 2008). Much of the earlier research has neglected the crucial division of risks as originating either within a chain or in the outside environment. In order to make such a distinction, the sources of uncertainty need to be separated (Trkman and McCormack, 2009).

Supply-chain disruptions may have long-term negative effects on a firm's financial performance (Tang, 2006). Risks come in many forms. Firstly, they may be operational and considered minor in terms of consequences, but they occur regularly. They may cause disturbances in the supply chain that are not perceived to be serious, but if they occur simultaneously or create a snowball effect they have serious consequences. Secondly and more commonly, they may be disruptive, described by Tang (2006) and Knemeyer et al. (2009) as low probability-high consequence (LP-HC) events. Such events may unexpectedly disrupt the flow of material at any time.

There are numerous categorizations of supply-chain risks in the literature, and their applicability depends on the chain in question. Blackhurst et al. (2008) argue that the most important step in the process of risk assessment is the selection and definition of the categories, which can be weighted, compared and quantified. The current literature offers many options, some of which are industry-specific and others are more general. Mason-Jones and Towill (1998)

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