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Risk management abilities in multimodal maritime supply chains: Visibility and control perspectives

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ABSTRACT

Supply chain complexity and disintegration lead to increased uncertainty from a stakeholders' perspective, which is emerging as one of the major challenges of risk management. The ability to identify risks has weakened, as the responsibility of supply chain risk management is handed over to outside service providers. Regardless, the risks, their visibility and their impact depend on the position of the companies in the supply chain. The actors in the chain must therefore collaborate to create effective risk management conditions. This challenging situation is especially pronounced in multimodal maritime supply chains, where the risks and actor focality are high. This paper contributes to current risk management literature by providing a holistic and systemic view of risk visibility and control in maritime supply chains. The study employs broad-based, qualitative interview data collected from actors operating in southern Finland and the Gulf of Finland as well as an expert-panel assessment of the related risk management abilities. The results show a high level of variance in the level of risk identification and visibility between the actors in question. This further suggests that collaboration in supply chain risk management is essential, as an awareness of the risks and their control mechanisms do not necessarily reside in the same company.

1. Introduction

Complexity and disintegration in the supply chain lead to increased uncertainty, which has emerged as a major challenge to risk management. Several drivers are dividing these functions among a growing number of actors, which decentralises relevant knowledge in the supply chain. Because of such developments, risk visibility beyond the companies' own functions diminishes. Thus, the ability to identify risks decreases. As a consequence, the competitiveness of individual actors becomes increasingly dependent on partner collaboration. Indeed, demands for such collaboration have moved the competition among actors from the company-to-company level to the supply chain–to–supply chain level (e.g. Ketidis et al., 2008; Pereira, 2009). Although several safety measures have been implemented over the last decade in the shipping industry (see e.g. Dobie, 2015; IMO, 2012), they often fail to consider the larger supply chain perspective; thus, risks remain a major concern in the field (Chauvin et al., 2013). Indeed, several authors have noticed the increased complexity of relationships and operations in supply chains (e.g. Kwesi-Buor et al., 2016; Gambatese and AlOmari, 2015; Achurra-Gonzalez et al., 2016). A deeper understanding of risk management in a complex multimodal context is therefore needed in maritime logistics (Luo and Shin, 2016).

Harland et al. (2003) conclude that less than 50% of the risk in the supply chains they examined was visible to the focal company. This issue sparked theoretical and practical discussions concerning the literature on supply chain risk management (e.g. Blos et al., 2009; Ellegaard, 2008; Jüttner et al., 2003; Levary, 2007; Tang, 2006). According to Enslow (2006), the lack of risk visibility in the supply chain process was a major concern for about 79% of the companies in their sample of 150 large, global enterprises. In fact, supply chain visibility has recently received increased attention (e.g. Christopher and Lee, 2004; Caridi et al., 2010; Lee et al., 2014), and given that disintegration has made organisations unaware of what goes on in their supply chains, there is a clear need for it. Thus, it can be argued that a firm's ability to identify risks has decreased as the visibility of and control over supply chain operations have fallen into the hands of outside service providers (Manuj and Mentzer, 2008). It is therefore worth investigating the selection and implementation of risk management strategies in supply chains across borders (Achurra-Gonzalez et al., 2016; Manuj and Mentzer, 2008).

The recent financial crisis has emphasised the role of supply chain risk management for several companies (Blome and

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Schoenherr, 2011), and in many ways, supply chains are more vulnerable than ever before (Wagner and Neshat, 2010). In maritime supply chains, the consequences of realised risks are seen in the US port labour disputes. The 11-day lockout in 2002 was estimated to cost $15.6 billion, and the latest 2015 shut down cost approximately $2 billion a day (Gorman, 2015). During the lockout periods, the impact spread to the other modes of transport as well; the sudden increase in international airfreight demand, for example, skyrocketed prices and filled the limited transportation capacity for many routes. While maritime supply chains form around 90% of international trading and risk management worldwide, these measures seem insufficient. Sadly, this paradigm will not likely change (Chauvin et al., 2013; Heckmann et al., 2015).

The need for supply chain risk management is evidenced in the results of Snell's (2010) study, which show that 90% of the responding companies fear supply risks, whereas only 60% feel confident or knowledgeable about such issues. Moreover, Christopher et al. (2011) report that most companies do not have a structured management and mitigation system covering supply chain risks. It is therefore no surprise that risks are considered the main reason why the desired performance is not achieved in supply chains (e.g. Tummala and Schoenherr, 2011; Blackhurst et al., 2005; Craighead et al., 2007; Hendricks et al., 2009). While the latest studies show a strong correlation between risk visibility and supply chain performance (Lee et al., 2014), the effects on supply chain risk management are still under-explored. Furthermore, while there is increasing awareness of supply chain accident and risk management among practitioners, the concepts of and the causalities between them are still in their infancy. There are also insufficient conceptual frameworks and empirical findings to provide a clear picture of the phenomenon of risk management in global supply chains (Jüttner et al., 2003; Jüttner, 2005; Manuj and Mentzer, 2008; Vilko, 2012). In line with this, Lavastre et al. (2012) suggest the need for more case studies on how different companies perceive and assess supply chain risks. Indeed, scholars have pointed out the shortage of empirical research in the area (e.g. Sodhi et al., 2012) and the need for understanding from a broader perspective rather than a narrow viewpoint that focuses on risk causation based on specific events (e.g. Hughes et al., 2015). Current literature seems to suggest that future research should focus on providing more holistic and systems approaches and models to enable a more comprehensive understanding (Alyami et al., 2016; Hughes et al., 2015). Our study aims to highlight and explore these research gaps and practical issues.

When considering the maritime perspective in supply chain risk management, many studies concentrate on security aspects (e.g. Barnes and Oloruntoba, 2005; Yang, 2011). This study's main aim, however, is to improve the decision making process in maritime supply chain management through improved risk visibility and control. Ultimately, such improvements can reduce risks and improve safety, efficiency and productivity. To this end, we will develop a holistic, analytical framework of risk visibility and control that the actors in the supply chain can utilise. The study is based on current supply chain risk management literature and empirical findings derived from extensive interviews and expert-panel data. The companies in the study belong to a maritime supply chain operating from the Baltic Sea to inland Finland. Even though several studies explore supply chain risk management (e.g. Blos et al., 2009; Ellegaard, 2008), few are concerned with maritime supply chains. In addition, there is no research that systematically addresses risk visibility and control—and the related collaboration requirements—in the same framework.

In this study, we first identified the risks in the supply chain between the Gulf of Finland and mainland Finland. We conducted interviews with 40 individuals in private and public organisations and asked seven experts from different parts of the chain to assess the risks the interviewed individuals identified. Using these data, we examined the risks and analysed them in terms of impact concentration. We then developed an analytical tool to examine the visibility and controllability of supply chain risks.

These results contribute to the existing literature on supply chain risk management by examining the multidimensional, often dispersed nature of risk impact as well as management abilities in terms of visibility and control regarding these risks. In particular, we reviewed the nature of risks according to their source (e.g. endogenous or exogenous) and in regard to the categories of their impact (e.g. causing costs, quality damages and time delays). Existing literature adequately covers the former perspective, but the latter has been less addressed. Furthermore, we examined management abilities in terms of the controllability and visibility of these risks as well as the role of supply chain collaboration in improving these abilities. Overall, in providing a systematic view of the manageability of risks in a multi-actor context, these results contribute to and complement the existing supply chain risk management (e.g. Jüttner, 2005; Chopra and Sodhi, 2004; Rao and Goldsby, 2009) and maritime supply chain literature (Lam, 2012; Mokhtari et al., 2012; Berle et al., 2011).

2. Theoretical background

This section discusses and reviews the key concepts and approaches related to supply chain risk management—namely, supply chain risks and their visibility and controllability—as covered in recent literature.

2.1. Supply chain risk management

An increasing amount of risk in supply chains is a current logistics trend (Minahan, 2005), and according to Singhal et al. (2009), disruptions are a critical issue for many companies. More recently, scholars have emphasised the importance of further studying supply chain risks and their management (e.g. Lam and Dai, 2015; Wiengarten et al., 2016). Supply chain risk management is defined as "the identification of potential sources of risk and implementation of appropriate strategies through a co-ordinated approach among supply chain members to reduce supply chain vulnerability" (Christopher et al., 2003). Similarly, maritime supply chain risk management can be defined as the "process of making and carrying out decisions that will minimise the adverse effects of accidental losses, and is based on risk assessment methods involving co-operation and communication between all members involved in maritime supply chain activities" (Yang, 2011).

Supply chain risk management has been studied from quantitative and qualitative perspectives (e.g. Tang, 2006; Heckmann et al., 2015). Typically, the quantitative approach is considered meaningful when a sufficient amount of reliable data and expertise is available; otherwise, the qualitative approach is more appropriate (e.g. Singhal et al., 2011; Vilko et al., 2016). Due to the nature of this study, we rely mostly on the qualitative approach to propose a practitioner-oriented framework for supply chain risk management.

An enterprise's typical risk management process consists of the following phases: risk or hazards identification (commonly referred as risk identification); risk assessment; decision making; and the implementation of risk management actions and monitoring. Risk identification is a fundamental phase in the risk management process. By identifying risk events, hazards and risk sources, a decision maker or a group of decision makers become aware of events or phenomena that cause uncertainty. The main focus of risk identification is to recognise future uncertainties in order to manage these scenarios proactively (Hallikas et al., 2004). Jüttner et al.

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(2003) identify four key aspects of supply chain risk management: (1) assessing the sources of risk events, (2) defining the adverse consequences, (3) identifying the risk drivers and (4) mitigating the effects on the supply chain. Blackhurst et al. (2008) argue that the most important step during the risk assessment process is the selection and definition of the categories of risk, which can be weighted, compared and quantified. The overall performance of the risk management systems implemented at both intra- and inter-organisational levels is typically highly dependent on the supply chain's holistic management (Sandhu and Helo, 2010). According to Soosay et al. (2008), inter-organisational relationships in supply chains have become increasingly important, and as Hallikas et al. (2004) claim, an effective collaborative process in risk management requires that the supply chain have a risk management mindset and culture.

2.2. Risk

Literature on supply chain management defines risk as purely negative and leading to undesired results or consequences (Harland et al., 2003; Manuj and Mentzer 2008). A standard formula for the quantitative definition of such risk is:

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

Risk is defined as the probability (P) of loss and the scope of its consequences (I) (Mentzer et al., 2001). This formula is applied in our analysis.

Risk also comes in many forms. First, operational risks may occur regularly yet can be considered both low or high in terms of consequences. Such concerns may cause both serious and less serious disturbances in the supply chain (Knemeyer et al., 2009). Second, and more commonly considered, disruptive risks are described as low-probability, high-consequence events (Tang, 2006; Knemyer et al., 2009). Such events may unexpectedly disrupt the flow of material in the supply chain at any time. Like most of the supply chain risk literature, we assume that events are the decisive factors that determine risk (e.g. Heckmann et al., 2015; Waters, 2007).

Risk sources are considered to be important in supply chain risk management (Rao and Goldsby, 2009). Peck (2005) delineates the sources of risk as deriving either within the supply chain or from the external operational environment. Further, from the perspective of risk analysis or risk management, the nature of the risk impact plays an important role. Vilko and Hallikas (2012) propose three types of risk impact for multimodal maritime supply chains: time-based, finance-based and quality-based. The aforementioned classification of risk sources and the nature of risk impact is applied in this research as illustrated in Fig. 1.

The Failure Mode and Effect Analysis (FMEA) framework is one method for practical risk analysis, which is used to investigate potential failure modes and their causes and effects in supply chain processes. FMEA enables the identification and analysis of potential failure modes in a system as well as the identification of actions that could eliminate or reduce the risk of service shortcomings (Chuang, 2002). To compute the risk priority number, it is possible to prioritise the failure modes relative to their probability of occurring, criticality (or severity) of failure and ease of detection. In a recent study Alyami et al. (2016) considered FMEA as an appropriate method for maritime supply chain risk analysis.

2.3. Visibility

Risk visibility is one of the key factors in supply chain risk management, which many authors recognise (e.g. Caridi et al., 2010; Al-Mudimigha et al., 2004). Most of them agree that visibility provides benefits in terms of operational efficiency (e.g. Smaros et al., 2003), productivity and effective planning (e.g. Petersen et al., 2005). Although there are many definitions of supply chain visibility, it is still debated whether they holistically capture its meaning, function and essence (Zhang et al., 2011; Francis, 2008). Barratt and Oke (2007) define it as "the extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operations and which they consider will be of mutual benefit". Francis defines it even more explicitly: "Supply chain visibility is the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events" (2008, p. 182). In the context of inter-organisational information systems, Kim et al. (2011) define visibility as "the extent to which partner firms' information/knowledge related to supply chain co-operation is visible to the focal firm through inter-organisational information systems". According to Wagner and Bode (2006), global supply chains typically have poorer visibility than local chains.

Visibility can be described as the outcome of an external integration. It is necessary but, on its own, is also an insufficient resource for organisations to manage risk (Williams et al., 2013). Indeed, while visibility is argued to influence risk management efficiency, in the supply chain context, the information associated with visibility is typically dispersed across actors, functions and geographic regions. Only with the proper level of control over the risks and events can visibility be utilised to improve risk management (Williams et al., 2013).

End-to-end visibility is a key element in any strategy designed to mitigate and improve supply chain risk (Christopher and Lee, 2004). The contemporary focus of scientific literature also highlights measuring supply chain visibility (e.g. Caridi et al., 2014). The managerial and practical interest in visibility emerged through frameworks such as the FMEA model, where visibility is measured according to how easily hazards and failures can be detected. In the FMEA model, the higher a hazard's detection score (and thus the visibility), the lower the assessed risk of failure (Carmignani, 2009).

2.4. Controllability

A major difficulty in attaining effectiveness in supply chains relates to controlling and co-ordinating a chain across individual organisational boundaries (Van Veen-Dirks and Verdaasdonk, 2009). According to Levary (2007), this relates strongly to the business partners in the chain because those actors have limited control over the choices their partners make. To overcome this problem, information exchange and other types of collaboration are required (Wong and Acur, 2010).

Many authors associate co-ordination with control in supply chains (e.g. Kampstra et al., 2006; Van Veen-Dirks and Verdaasdonk, 2009). Seuring (2006) points out that there is no single unified concept of control in the literature and argues that the cornerstones of supply chain control are rationality, co-ordination and information. For the sake of conceptual clarity, risk control is defined here similarly to Heckmann et al.'s (2015) delineation: "a risk management action based on findings from risk analyses to implement changes in the supply chain aimed at mitigating risk exposure". Supply chain control may be acquired either directly from the actor in question or indirectly via another actor in the chain. In supply chain risk management studies, controllability is often intertwined and sometimes overlaps with the concept of risk control. Risk control is typically recognised as a phase of the risk management process where actions are implemented to mitigate risks (Tummala and Schoenherr, 2011).

By looking at the presented concepts, it is clear that supply chain risk management relies heavily on the identification of risks via

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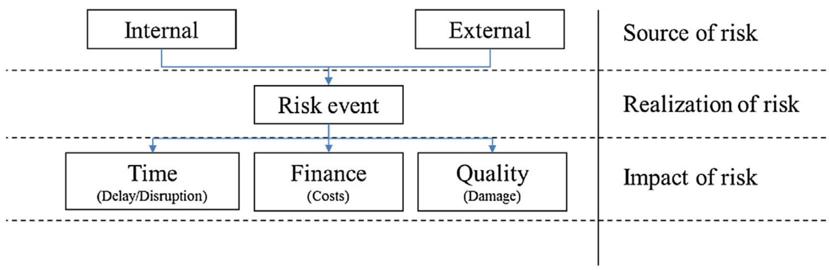

Fig. 1. The source of risk and the nature of risk impact.

supply chain visibility, on the control of those risk events and the related operations, and prioritizing resources to meet supply chain objectives. However, these concepts are strongly connected to supply chain collaboration, which in itself is an essential element of supply chain risk management. In many ways, the concepts of supply chain risk management are still developing, and explicit causal relationships are difficult to form (e.g. Vilko, 2012; Lavastre et al., 2012).

3. Empirical study

This study is based on the integrated literature review and empirical evidence. The empirical portion focuses on the supply chain between the Gulf of Finland and the Finnish mainland in terms of the risks involved and their management. The research was carried out as part of a larger study on cargo flows in the Gulf of Finland in emergency situations and in a context in which interviews were conducted with individuals from a cross-section of organisations in the chain.

Given the limited research on how supply chain actors deal with visibility and control issues, we chose the explorative case study as our research approach. To tap into the professional supply chain actors' experience and knowledge, we adopted a discovery-oriented approach and used semi-structured interviews as the primary method of data collection (Zaltman et al., 1982; Yin, 1989). The chosen approach is twofold in that it enables an investigation into the relationships between individual companies and provides a holistic view of the supply chain being reviewed. We conducted the case study by interviewing practitioners from different parts of the chain and carefully listening to their views. We then mapped the process and the chain's structure and analysed risk management and co-operation levels. The aim was to understand the extent to which the risks facing the supply chain between the Gulf of Finland and inland Finland were visible to the practitioners and how they could be controlled.

3.1. Methodology

The qualitative and explorative research approach was considered appropriate to gain theoretical and empirical insight into the topic because it has not received much context-based research attention (Yin, 1989). Moreover, from the theory building perspective, the applied method worked well in developing and testing the approach. It also enabled an exploration of the causal relations and linked causes and outcomes as well as an understanding of the sensitivity of the concepts to the context (George and Bennett, 2005). The study form worked well in serving the information-oriented focus of the research and discovering causalities and meanings of the phenomenon (Yin, 1989; Jensen and Rodgers, 2001).

We explored the risks in the maritime supply chain in three sequential stages. The first step was to identify risks through in-depth interviews with practitioners. In the second step, the identified risks were analysed by members of an expert panel comprising practitioners representing different operations in the chain. The third step was to analyse the visibility and controllability of the risks.

The qualitative interviews in the first phase of the empirical research process identified the risks in the multimodal supply chain. The structure of hazard identification and risk analysis method FMEA was applied, where risk events their sources (causes) and impact (effect) are systematically considered. FMEA is considered a solid method for risk identification (e.g. Crawley and Tyler, 2003; Alyami et al., 2016) and was also used by some of the interviewed organisations. Given that neither the phenomenon nor the context was evident, this approach was considered appropriate in terms of making sense of the phenomena by interpreting the meanings people attach to them (Yin, 1989). This facilitated the in-depth, detailed study of the phenomenon from the interviewees' perspective. The approach typically entails no prior hypothesis setting, and the researcher should have no prior assumptions (Voss et al., 2002). Sampling is generally discretionary, but the numbers may be small and fail to provide statistical value (Eisenhardt, 1989).

Face-to-face interviews were conducted with 40 actors from different companies (see Table 1). At the beginning of each one, the interviewee was promised anonymity, and permission to use a tape recorder was obtained. The sessions were recorded, and the audio files were then transcribed to text files to facilitate later examination. The semi-structured interviews focused on supply chain risks and their impacts, and a discovery-oriented approach was used to tap into the professionals' experience and knowledge (Zaltman et al., 1982; Yin, 1989). The style was discursive, and there were no predetermined response options. Themes and questions were discussed at random to enable a natural, conversational style and allow the interviewees' lead to be followed. To obtain a holistic view of the operations, the interviewees were asked to describe their own processes and related risks in a given supply chain and to take these into account at a broader level and in different stages of the supply chain. The interviewee pool included informants from different parts of the supply chain, and we collected various perspectives on the key processes and activities and their related risks at both the actor level as well as the broader supply chain level. Therefore, the overall data provided a holistic, multi-actor perspective of the supply chain and the potential emergence of risks and their consequences.

The next stage after the interview process was to organise an expert panel involving seven persons to constructively validate (e.g. Cresswell and Miller, 2000; Lincoln and Guba, 1985) the interview results and enable further iterative analyses of the risks and the nature of their impact. Internet-based ThinkTank^{TM} real-time group collaboration software was used to conduct the session. The system allows real-time computer-based brainstorming at the same time wherever the Internet connection and computer is available. The motivation for using such systems is in the effectiveness for producing new ideas compared to the traditional group processes. The system is also designed with the anonymity of opinions nevertheless, free group discussion is ordinary during the ses-

Table 1
Interviewed actors in the supply chain.

Actor	Interviews	Company size	Interviewee positions	Actor role in the supply chain
Trucking company A	2	Medium	CEO, Transport Manager	Truck transportations, warehousing and distribution
Trucking company B	2	Medium	CEO, Transport Manager	Inland truck transportations, warehousing and distribution
Trucking company C	1	Medium	HR Manager	Truck transportations (Finland)
Railway operator	2	Large	Director of Railway Logistics, Hazardous Materials Transport Expert	Railway transportations
Shipping company	1	Medium	Managing Director	Shipping, stevedoring and warehousing
Port Administration A	2	Medium	CEO, Safety and Security Manager	Port administration and security
Port Administration B	1	Small	Traffic Manager	Port logistics administration
Railway Transport Agency	1	Large	Senior Inspector	Safety and security of railways
Port Administration C	2	Medium	Port Manager, Safety and Security Manager	Port management, port safety and security management
Transport agency	1	Large	Traffic System Specialist	Engineering and developing traffic systems and routes
Logistics consultant	1	Micro	CEO	Logistics consultancy, expert services
Insurance company	2	Large	Chief Underwriter, Risk Manager	Logistics insurance and risk management
Pulp and paper company	5	Large	Logistics Manager (2), Terminal Superintendent, Supply Manager (2)	Logistics management, terminal activities, warehousing, scheduling, demand and supply management
Shipping company	4	Large	Production and Logistics Manager, Fleet Manager, Maritime Personnel Manager, Traffic Manager	Production and fleet scheduling, HR management, Traffic and logistics management
Customs,	2	Large	Director of District, Supervisor	Security and safety supervision, import/export cargo inspections.
Stevedore	1	Large	Sales and Marketing Manager	Stevedoring, forwarding and warehouse management.
Forwarding company	1	Large	Senior Vice President	International logistics
Logistics operator A	1	Small	Operations Manager	Managing logistics operations in Finland
Logistics operator B	1	Large	Risk Manager	Responsible for organisational risk management
Logistics operator C	1	SME	Director Overland	International supply chains
Logistics operator D	2	Large	Production Director	Supply-chain management in Finland
Defence forces	1	Large	Commodore	Safety and security of the Gulf of Finland and the coast of Finland
National Emergency Supply Agency	2	Medium	Chief of Preparedness (Logistics), Chief of Preparedness Research	Ensuring the emergency preparedness of the logistics sector in Finland
Coastguard	1	Large	Border Safety Expert	Safety and security of the Finnish sea boarder in the Gulf of Finland

sions. The panel comprised practitioners from the supply chain in question who had been previously interviewed. The researchers selected the expert panellists following three criteria: First, based on the informants' knowledge of supply chain operations and causalities and their understanding of the field. The seven selected experts were considered to hold relatively high expertise regarding the studied supply chain. Second, their organisations' positions in the supply chain were evaluated. The organisations were considered major actors in the chain and were therefore assumed to have the best knowledge about its risks. Third, the informants' positions in the organisations and the supply chains identified by their job descriptions were deliberated. Finally, seven panel representatives were selected to symbolise different parts of the supply chain process.

By using actors with various positions in the studied supply chain, multiple perspectives were synthesised, and a holistic picture emerged. Every risk driver was considered separately, and the risks were introduced in a random order without any categorisation to ensure the values were determined separately. The software allowed for participants to change their responses and enabled the tracking of responses from other interviewees. The experts were also given an opportunity to provide additional information about the risks. The three-staged process included an: 1) investigation of the risks (vulnerabilities); 2) analysis of the impact concentrations in the supply chain; and 3) analysis of visibility/controllability. The research group then verified the interview results from their own perspectives to determine the likelihood of risk as well as the nature of risk impact and its values.

To conduct the maritime supply chain analysis, each of the seven experts analysed the identified risks based on likelihood and impact, which were evaluated on a scale of 0, 1, 3 and 9, where 0 implied no likelihood or impact and 9 denoted a high likelihood or impact. The scale was adapted from the Quality Function Deployment design method (e.g. Akao, 2004). This is commonly used in the context of developing a new product or service (Chan and Wu, 2002), but it is also applied in the FMEA framework (Paciarotti et al., 2014), supply chain risk management (Pujawan and Geraldin, 2009) and multimodal maritime supply chain risk assessment (Vilko and Hallikas, 2012). The 0, 1, 3 and 9 scale was used because it is a leaner, faster tool that preserves its effectiveness and ensures a satstisfactory outcome (Paciarotti et al., 2014). The average of the different scores the experts determined was calculated to create a holistic perspective of the supply chain. Expert were able to see the scores given by other experts in the assessment which increased the consistency of the expert judgments. Furthermore, an assessment of the nature of risk impact was based on a risk's main, direct impact on supply chain operations.

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3.2. Case and research process

The supply chain in question runs between southern Finland and the Gulf of Finland, with an approximate length of 200 kilometres, and includes maritime and land transport before and after the port. The Gulf of Finland is situated between Finland, Estonia and Russia. The volume of transported cargo in the Gulf grew substantially over the last decade, and thus far, there have been fewer accidents relative to traffic density than the global average (VTT, 2002; FMA, 2009). The inland leg of the supply chain is located in southern Finland, where the infrastructure is in good condition. Southern Finland also has the highest density of roads and railways in the country and accounts for about half of the total population (Rissanen et al., 2013).

The selected supply chain and case companies were chosen in collaboration with the National Emergency Supply Agency, the role of which is to ensure the security of supply in Finland. All the companies interviewed are part of the multimodal maritime supply chain and act in various roles, representing different parts of the chain (see Table 1) in which port events account for the majority of activities. The organisational sizes are based on the European Commission's (2003/361) definitions.

The interviewees perform a range of duties related to supply chain and risk management. These vary in terms of position, but all participants have an extensive understanding of their company's operations and risks. This was considered essential to an accurate analysis. We therefore contacted the companies and requested the names of the individuals who would be most suitable given the scope of the research, and further suggestions were given in the earlier interviews. A group of three to four researchers with different specialisations conducted the interviews to ensure as broad a view of the subject as possible and to guarantee the reliability of the study and its viability as a basis for further work. The multidisciplinary group discussed and reached a consensus regarding the responses after each interview, thus validating the findings through researcher triangulation (e.g. Cresswell and Miller, 2000).

The constructive part of the research process proceeded in three stages: 1) investigation of the risks (vulnerabilities), 2) analysis of the impact concentrations in the supply chain and 3) analysis of visibility and controllability. These steps are described in the following sections.

Focusing on one step at a time enabled a logical approach to analysing and comparing the vast set of risks encountered. After identifying the risks involved in the supply chain, we concentrated our analysis towards risk visibility and controllability according to their sources. Namely, we focused on the most and least concentrated exogenous and endogenous risks. The risk impact concentration values received from the expert panel responses were then selected according to their score, namely the risks that scored the highest (over 80%) or the lowest (50% or less) on one dimension—either time delays, additional costs or quality damages—suggesting a more scattered impact. We named these two categories unidimensional and multidimensional risks, making the distinction to determine whether the concentration of a risk in one dimension made it more visible and controllable. This kind of holistic picture of vulnerabilities is needed to recognise the visibility and controllability of the risks connected to different actors.

We then used an expert panel to evaluate the level of visibility and controllability with regard to the examined risks. As in the previous step, both aspects were evaluated on a scale of 0, 1, 3 and 9, and the results were obtained through group consensus. The product of these variables represents a company's ability to manage the risk in question. The evaluated risks were selected according to impact concentration in two categories: risks with a unidimensional impact and those with a dispersive impact, depending on the actor (coded as multidimensional, or risks with 50% or less concentration in terms of the nature of the impact).

4. Results and analysis

4.1. Risk analysis

The conducted interviews revealed how risks the practitioners identified varied between the companies. The identification of supply chain risk and overall risk management was at a lower level in the smaller companies (e.g. trucking) than those operating at a broader level of the supply chain. Typically, the lower level businesses had only elementary risk management processes in their organisations. Surprisingly, some of the medium-sized trucking companies reported relying exclusively on intuition in their risk management, and their overall risk consciousness was poorer compared to those enterprises with more sophisticated methodologies. There were also significant personal differences between the managers and their interpretations. Overall, risk management capabilities were better in the larger companies that had introduced analytical tools for this purpose and elected personnel responsible for risk management. These actions increased their awareness of risk issues mostly in their own organisations; typically, their management tools did not cover a large portion of the supply chain.

Table 2 breaks down the risk analysis results. Of the 103 risks identified in the interviews, the 37 with the largest risk impact accounted for 60.5% of the risk scores the experts provided. These were chosen for a more detailed analysis. The first score columns in Table 2 indicate the average score from the experts answers (Likelihood and Impact) from which the risk value is calculated, the% column refers to the risk scores relative share of the total sum value of all risks (657,2). When we estimated the nature of the risk impact were calculated according to their relative importance of the overall score, time delays accounted for 51.7% (327) of the total risk scores (all risk natures counted 633), additional costs for 36.5% and quality damage for 11.8%. Hence, most of the risks lead to time delays if realised, which have the biggest impact. The risk concentration in Table 2 denotes the relative share of the risk's highest scored nature of impact. For example in the first row the risk concentration of fuel price (85,7%) is the share of additional costs (6) from the total score possible (7).

The exogenous and endogenous risks differed in the amount identified (65 and 38 respectively) and their nature of impact. The exogenous risks had a greater impact in terms of time and costs, whereas the endogenous were responsible for more of the quality damage. Exogenous risks accounted for approximately 53% of the time delays, and endogenous risks made up about 49%. Additional costs accompanied 38% of the exogenous risks and 33% of the endogenous. The biggest difference was seen in quality damages, where the exogenous risks counted for only 8% and endogenous risks comprised 18%. The next step continued the analysis by exploring the visibility and controllability of the identified risks, which is described in the next section.

4.2. Risk visibility and controllability analysis

The interviews revealed that visibility and controllability do not necessarily coincide. To analyse risk visibility and controllability, a framework was developed (see Table 3) to determine the actors' visibility and controllability scores for the previously identified risks. As can be noticed from Table 3, in a situation where an actor has visibility of a risk event, that actor may lack the ability to control the risk, or vice versa. It is therefore important to recognise the actors that maintain visibility of the relevant risk and those

Table 2
Risk sources and concentration.

	Risk event	Likelihood	Impact	Risk	%	Time delay	Additional costs	Quality damages	Yhteensä	Risk concentration
Exogenous	Fuel price	5.29	5.29	27.94	4.25%	1	6	0	7	85.7%
	Ice conditions in GoF	4.43	4.71	20.88	3.18%	4	3	0	7	57.1%
	Unpredictability of Russiaís regulations	4.43	4.14	18.35	2.79%	2	5	0	7	71.4%
	Strikes	2.43	6.43	15.61	2.38%	2	4	1	7	57.1%
	Russiaís border policies	3.00	5.00	15.00	2.28%	3	2	1	6	50.0%
	Russiaís economic politics	2.43	5.29	12.84	1.95%	1	5	1	7	71.4%
	Fierce competition	3.86	3.00	11.57	1.76%	2	5	0	7	71.4%
	Oil catastrophe	2.14	5.29	11.33	1.72%	1	4	2	7	57.1%
	Long distances	3.00	3.57	10.71	1.63%	3	2	0	5	60.0%
	Bottlenecks in routes	2.14	5.00	10.71	1.63%	3	4	0	7	57.1%
	Economical crisis	2.43	3.86	9.37	1.43%	3	4	0	7	57.1%
	Operating in heavy traffic	3.00	3.00	9.00	1.37%	4	1	1	6	66.7%
	Crossing traffic in GoF	2.71	3.29	8.92	1.36%	1	3	2	6	50.0%
	Shallowness of the straits	2.43	3.57	8.67	1.32%	3	2	1	6	50.0%
	Difficult navigability	3.00	2.71	8.14	1.24%	4	2	1	7	57.1%
	Storms	2.71	3.00	8.14	1.24%	6	1	0	7	85.7%
	Internet connection problem	2.71	3.00	8.14	1.24%	4	3	0	7	57.1%
	Railway network capacity	3.29	2.43	7.98	1.21%	6	1	0	7	85.7%
	IT vulnerability	2.43	3.29	7.98	1.21%	3	3	0	6	50.0%
	Military conflict	1.14	6.71	7.67	1.17%	2	2	1	5	40.0%
	Slipperiness and snow	3.57	2.14	7.65	1.16%	4	3	0	7	57.1%
	Fire	1.57	4.71	7.41	1.13%	2	4	1	7	57.1%
	Old shipping lanes	2.71	2.71	7.37	1.12%	6	1	0	7	85.7%
	Route restrictions	1.57	4.43	6.96	1.06%	5	2	0	7	71.4%
	Electricity blackout	1.29	5.29	6.80	1.03%	4	2	1	7	57.1%
	Traffic accidents	2.71	2.43	6.59	1.00%	5	2	0	7	71.4%
	Other trade unions actions	2.43	2.71	6.59	1.00%	1	6	0	7	85.7%
	Capacity of road network	2.14	3.00	6.43	0.98%	6	1	0	7	85.7%
	Merchant fleet foreign ownership	3.00	2.14	6.43	0.98%	3	2	1	6	50.0%
	Break down of special structure	1.29	4.71	6.06	0.92%	3	3	0	6	50.0%
	Capacity problems in railroad traffic	2.14	2.71	5.82	0.89%	5	2	0	7	71.4%
	Terrorism	1.29	4.43	5.69	0.87%	2	2	2	6	33.3%
	Nuclear disaster in nearby plants	1.00	5.57	5.57	0.85%	3	2	0	5	60.0%
	Underwater mines	1.00	5.00	5.00	0.76%	1	2	2	5	40.0%
	Traffic jams	3.86	1.29	4.96	0.75%	7	0	0	7	100.0%
	Flying accident	1.29	3.86	4.96	0.75%	3	1	2	6	50.0%
	Explosion of gas line	1.29	3.86	4.96	0.75%	2	1	2	5	40.0%
	Infrastructure limitations	1.29	3.86	4.96	0.75%	2	4	0	6	66.7%
	Hurricanes	2.14	2.29	4.90	0.75%	5	1	0	6	83.3%
	Problems in telephone connections	1.57	3.00	4.71	0.72%	3	3	0	6	50.0%
	Russiaís railway capacity in the future	2.14	2.14	4.59	0.70%	5	1	0	6	83.3%
	Customs formalities and unclarities	1.57	2.71	4.27	0.65%	5	2	0	7	71.4%
	Political instability	1.29	3.29	4.22	0.64%	2	4	0	6	66.7%
	Fall of EU	1.14	3.29	3.76	0.57%	1	5	0	6	83.3%
	Wind	2.71	1.29	3.49	0.53%	5	0	0	5	100.0%
	Economical problems of Baltics	1.86	1.86	3.45	0.52%	2	4	1	7	57.1%
	Regional epidemic	1.57	2.14	3.37	0.51%	4	3	0	7	57.1%
	Traffic route breakdowns	1.29	2.43	3.12	0.48%	6	1	0	7	85.7%
	Lightning	2.43	1.29	3.12	0.48%	4	1	0	5	80.0%
	Organized Crime	1.29	2.43	3.12	0.48%	2	2	1	5	40.0%
	Forwarding agency's monopoly	1.29	2.29	2.94	0.45%	2	4	0	6	66.7%
	Finland's small and unattractive markets	1.86	1.57	2.92	0.44%	3	3	0	6	50.0%
	Infectious diseases	1.29	2.14	2.76	0.42%	4	2	0	6	66.7%
	Heavy rains	2.43	1.00	2.43	0.37%	3	1	1	5	60.0%
	Transportation routes from ports	1.29	1.86	2.39	0.36%	7	0	0	7	100.0%
	Driving time legislation	1.86	1.29	2.39	0.36%	6	1	0	7	85.7%
	Spying and espionage	1.29	1.86	2.39	0.36%	2	2	2	6	33.3%
	Phytosanitary, sanitary, veterinary risks	1.29	1.86	2.39	0.36%	2	3	0	5	60.0%

Table 2 (*Continued*)

	Risk event	Likelihood	Impact	Risk	%	Time delay	Additional costs	Quality damages	Yhteensä	Risk concentration
	Intersecting rail and road traffic	1.29	1.57	2.02	0.31%	4	0	1	5	80.0%
	Floods	1.57	1.29	2.02	0.31%	3	2	0	5	60.0%
	Climate change	1.33	1.33	1.78	0.27%	3	1	1	5	60.0%
	Problems in water deliveries	1.33	1.33	1.78	0.27%	2	2	0	4	50.0%
	NATO-membership	1.29	1.29	1.65	0.25%	3	2	0	5	60.0%
	Smuggling of people	1.29	1.29	1.65	0.25%	3	1	2	6	50.0%
	Vessel corrosions from environmental toxic	1.29	1.14	1.47	0.22%	1	1	3	5	60.0%
Endogenous	Ship collisions	2.14	6.43	13.78	2.10%	1	5	1	7	71.4%
	IT-system vulnerability (virus etc.)	3.00	4.43	13.29	2.02%	1	5	1	7	71.4%
	Changes in schedules	3.86	3.00	11.57	1.76%	7	0	0	7	100.0%
	Railway operator's low service level	3.29	3.29	10.80	1.64%	5	1	1	7	71.4%
	Not enough personnel	3.29	3.29	10.80	1.64%	1	2	2	5	40.0%
	Fault in cargo/traffic control systems	2.71	3.86	10.47	1.59%	5	0	1	6	83.3%
	Chemicals	2.71	3.86	10.47	1.59%	2	3	1	6	50.0%
	Workers poor motivation	2.43	3.86	9.37	1.43%	2	2	2	6	33.3%
	Irresponsibility	3.00	3.00	9.00	1.37%	1	5	1	7	71.4%
	Stoppages made with cargo onboard	2.71	3.00	8.14	1.24%	7	0	0	7	100.0%
	IT-systems connectivity	3.00	2.43	7.29	1.11%	2	5	0	7	71.4%
	Shipment quality information	1.86	3.86	7.16	1.09%	2	0	4	6	66.7%
	Railway operators' monopoly	1.86	3.86	7.16	1.09%	1	6	0	7	85.7%
	Insufficient knowledge	2.14	3.00	6.43	0.98%	2	2	3	7	42.9%
	Drunken drivers	3.86	1.57	6.06	0.92%	5	0	2	7	71.4%
	Problems with software	3.00	1.86	5.57	0.85%	3	3	0	6	50.0%
	Schedule change information	1.86	3.00	5.57	0.85%	6	1	0	7	85.7%
	Financial standing of the customer	2.14	2.57	5.51	0.84%	2	4	0	6	66.7%
	Shipment capacity	2.71	2.00	5.43	0.83%	4	1	0	5	80.0%
	Document interpretation problems	1.57	3.29	5.16	0.79%	4	2	1	7	57.1%
	Unwillingness to share information	1.86	2.71	5.04	0.77%	2	1	4	7	57.1%
	Shipping company's monopoly	1.86	2.71	5.04	0.77%	2	4	0	6	66.7%
	Cargo handling equipments condition	1.86	2.71	5.04	0.77%	2	3	1	6	50.0%
	Insufficient railroad wagons	2.14	2.14	4.59	0.70%	5	1	0	6	83.3%
	Not understanding the big picture	2.14	2.14	4.59	0.70%	1	2	3	6	50.0%
	Social problems	1.86	2.43	4.51	0.69%	3	1	2	6	50.0%
	Insufficient documentation	1.86	2.43	4.51	0.69%	3	2	1	6	50.0%
	Organizational borders	1.57	2.14	3.37	0.51%	2	2	2	6	33.3%
	Terminal's monopoly	1.29	2.43	3.12	0.48%	2	4	0	6	66.7%
	Traffic law negligence	2.14	1.29	2.76	0.42%	4	1	1	6	66.7%
	Lack of intermodal equipment	1.00	2.71	2.71	0.41%	4	1	0	5	80.0%
	Condition of transport equipment	1.33	2.00	2.67	0.41%	2	1	2	5	40.0%
	Transportation company's permits	1.57	1.67	2.62	0.40%	3	1	0	4	75.0%
	Explosives	1.14	2.29	2.61	0.40%	3	2	0	5	60.0%
	Interpersonal relations	1.29	1.57	2.02	0.31%	2	0	4	6	66.7%
	Other hazardous materials	0.83	2.29	1.90	0.29%	3	1	0	4	75.0%
	Bankruptcy of big forwarding agent or operator	1.57	1.14	1.80	0.27%	5	2	0	7	71.4%
	Fertilizers	1.14	0.86	0.98	0.15%	2	1	1	4	50.0%
				657.2	100%	327(51,7%)	231(36,5%)	75(11,8%)	633(100%)	64.4%

that have the ability to control the risk. The method introduced here allows these risks to be identified and managed in accordance with the priority assigned to them. For example, the results show that the port administration, who had better visibility (9) as the central node of the supply chain with moderate control (3), anticipated the changes in schedules. However, the shipping company

Table 3
Risk management abilities in the supply chain.

	Maritime leg (Shipping company)					Port operations (Port Administrator)			Inland leg (Trucking company)					
	Risk	Risk concentration	Visibility	Controllability	RM ability	Visibility	Controllability	RM ability	Visibility	Controllability	RM ability	Average SCRM ability	Collaborative SCRM ability	Difference
Exogenous unidimensional risks with high impact concentration														
Fuel price	27.94	85.7%	3	1	3	3	1	3	3	1	3	3.7%	3.7%	0.0%
Storms	8.14	85.7%	9	1	9	3	1	3	3	1	3	6.2%	11.1%	4.9%
Capacity of railway network	7.98	85.7%	0	0	0	1	1	1	1	0	0	0.4%	1.2%	0.8%
Old shipping lanes (slow and narrow)	7.37	85.7%	9	1	9	3	3	9	1	0	0	7.4%	33.3%	25.9%
% of maximum ability			58.3%	8.3%	6.5%	27.8%	16.7%	4.9%	22.2%	5.6%	1.9%	4.4%	12.3%	7.9%
Exogenous multidimensional risks with low risk concentration														
Russiaís border policies in transit traffic	15.00	50.0%	1	0	0	1	0	0	3	1	1	0.4%	3.7%	3.3%
Crossing traffic in the Gulf of Finland	8.92	50.0%	9	3	27	1	0	0	0	0	0	11.1%	33.3%	22.2%
Shallowness of the straits	8.67	50.0%	9	1	9	9	1	9	1	0	0	7.4%	11.1%	3.7%
Information technologies vulnerability	7.98	50.0%	3	3	9	3	3	9	3	1	3	8.6%	11.1%	2.5%
Military conflict	7.67	40.0%	1	0	0	3	0	0	1	0	0	0.0%	0.0%	0.0%
% of maximum ability			51.1%	15.6%	13.9%	37.8%	8.9%	5.6%	17.8%	4.4%	1.2%	6.9%	11.9%	5.0%
TOTAL exogenous risk	11.07	64.8%	54.3%	12.3%	9.1%	33.3%	12.3%	4.7%	19.8%	4.9%	1.4%	5.0%	11.7%	6.6%
Endogenous unidimensional risks with high impact concentration														
Changes in schedules	11.57	100.0%	3	9	27	9	3	27	3	1	3	23.5%	100.0%	76.5%
Stoppages with cargo onboard	8.14	100.0%	3	3	9	3	1	3	3	3	9	8.6%	11.1%	2.5%
Railway operators' monopoly	7.16	85.7%	1	0	0	3	0	0	1	0	0	0.0%	0.0%	0.0%
Fault in cargo/traffic control systems	10.47	83.3%	1	3	3	3	3	9	3	1	3	6.2%	11.1%	4.9%
% of maximum ability			22.2%	41.7%	12.0%	50.0%	19.4%	12.0%	27.8%	13.9%	4.6%	9.6%	30.6%	21.0%
Endogenous multidimensional risks with impact concentration														
Chemicals	10.47	50.0%	3	9	27	3	9	27	1	1	1	22.6%	33.3%	10.7%
Not enough personnel	10.80	40.0%	3	1	3	3	1	3	3	3	9	6.2%	11.1%	4.9%
Workers poor motivation	9.37	33.3%	3	3	9	3	3	9	3	3	9	11.1%	11.1%	0.0%
% of maximum ability			34.2%	49.7%	16.1%	35.2%	48.9%	16.1%	27.0%	26.4%	7.8%	13.3%	18.5%	5.2%
TOTAL endogenous risk	9.71	70.3%	21.1%	36.0%	11.7%	30.5%	26.0%	11.7%	16.9%	13.1%	3.9%	9.1%	25.4%	16.3%

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(9) maintained control over those changes, and its visibility was only moderate (3). Indeed, the trucking company's ability to manage risks was quite limited (3), as controllability over the scheduling was low (1) and the visibility was only moderate (3).

The presented framework also illustrates the importance of collaboration in the supply chain: The far right columns of the tables represent the average risk management abilities of the supply chain with regard to the given risks. The third column from the right represents a situation where the visibility information on the risks is not exchanged and the control mechanisms are not shared with the partners. The second column from the right represents the same situation with the assumption of the benefits provided via supply chain collaboration in terms of visibility and controllability. Instead of average values, the latter column is calculated using the maximum values for the visibility and controllability. For example, for *Storms* in Table 3, the risk management ability of 6.2% represents the average value of supply chain risk management abilities calculated from the three legs. The collaborative supply chain risk management postulates that through collaboration the highest abilities are used, in this case storm visibility from the maritime leg, and thus the higher value (9) of visibility is used for all the legs, which increases the overall risk management ability to 11.1%. Furthermore, the far right column illustrates the differences in risk management abilities when collaborating or acting alone in the supply chain (in case of storm the benefits is 4.9%). It is clear that collaboration allows better risk management over the supply chain. The framework thus illustrates how individual companies can manage endogenous scheduling risks with a 23.5% capability. However, by collaborating and sharing information (giving the entire supply chain access to every actor's visibility and controllability), the score increases to 100% control over the schedule changes.

In terms of risk sources, the results show higher manageability for endogenous risks in general, as all the actors achieved higher scores in this context. Furthermore, multidimensional risks that are also exogenous have low manageability (4.4%), and they are particularly beyond the reach of trucking companies. However, in both risk source cases, collaboration—permitting better supply chain–wide visibility and controllability—brings clear benefits, as overall risk management abilities more than doubled in both cases.

Fig. 2 summarises the overall positioning of the identified risks in terms of their impact (x-axis), dispersion (y-axis) and endogeneity or exogeneity (legend type). The risks with the highest impact are situated on the right-hand side of the matrix, whereas the most dispersed risks (i.e. multidimensional with many types of effects) are situated in the upper part. Endogenous risks related to the supply chain actors' own activities are marked with a diamond, whereas exogenous risks (i.e. environmental, policy-related and other contingency issues) are marked with a square.

The bottom-left quadrant contains risks that have a minor impact but are quite concentrated in terms of their effect (i.e. unidimensional risks that affect only costs, time or quality—but not all three). Such risks are typically related to storms, drunk drivers, hazardous materials and other rare and/or minor events in terms of the overall supply chain.

The risks that have a minor impact but are highly dispersed (i.e. multidimensional) in terms of their effects (i.e. costs, time delay and quality) are listed in the upper-left quadrant. These types of risks are highly unlikely and only pose a minor threat to the supply chain. They are typically markedly different from events such as nuclear disasters, data breaches or organised crimes and are rather minor issues compared to insufficient documentation.

Risks that are concentrated on one type of high-impact effect are situated in the bottom-left quadrant. The most notable here is the price of fuel, which affects costs the greatest; however, the likelihood of price fluctuations is also real. Other risks identified in this quadrant include the unpredictability of Russia's regulations.

The upper right-hand corner contains the most difficult-to-manage risks, including those that have a significant impact and a highly scattered dispersion of effects. For instance, the somewhat likely and impactful event of labour strikes could affect costs, time delays and quality. Other high risk, dispersed events include Russia's border policies regarding transit traffic as well as ice conditions in the Gulf of Finland.

5. Discussion and implications

Supply chains are increasingly complex and vulnerable to various risks, and for a single actor, it is impossible to achieve a complete understanding of all interdependencies. Harland et al. (2003) suggest that less than 50% of the risk is visible to the focal company. The main objectives of this study were to identify and assess the risks affecting cargo flows in the Gulf of Finland and to analyse the visibility and control aspects of the focal supply chain. Our study shows that there were major visibility and controllability differences between the participating companies and individuals, which affect risk management in complex maritime supply chains. These results suggest that supply chain managers should take the source and nature of the risk impact into consideration and further explore the means to achieve better risk visibility and control. In fact, after conducting the study, we discovered that some of the most impactful and multidimensional risk-effect types of events had recently taken place (for example, Russia changed its border policies with regard to transit traffic, causing problems for Finnish-based logistics operators). All in all, the conceptual and methodological tools introduced, as well as the findings, illustrate the potential value of conducting systematic risk analyses. In doing this out results concur with recent research results in the field (e.g. Gambatese and AlOmari, 2015; Luo and Shin, 2016; Banda et al., 2015). In the following section, we discuss the key implications for research and practice followed by a discussion of the study's limitations and the potential for further research.

5.1. Implications for research

Supply chain risks are typically evaluated according to their source (e.g. Rao and Goldsby, 2009); however, the findings of this study reveal interesting aspects in terms of the nature of the risks and their impacts. In future research, it would be beneficial to categorise the risks according to their impact, which would provide a better view of a management team's ability to control them.

In the analysis conducted in this study, the risks varied considerably in terms of their impact and dispersion. The most impactful and dispersed were exogenous in nature. However, it can be seen from the results that endogenous-originated risks are easier to control in general for all the actors. The risk concentration/dispersion across unidimensional (e.g. only time delay) and multidimensional (e.g. causing costs, quality damages and time delay) was then analysed. The multidimensional risks of an exogenous nature were found to be especially hard to manage, although there was variation in this regard between actors. These results contribute to and complement the existing supply chain risk management (e.g. Jüttner, 2005; Chopra and Sodhi, 2004; Rao and Goldsby, 2009) and maritime supply chain literature (Lam, 2012; Mokhtari et al., 2012; Berle et al., 2011) by providing a systematic view of the manageability of risks in a multi-actor context.

Current supply chain risk management practices purportedly suffer from unclear and inadequate supply chain risk management measures that fail to consider the characteristics of modern supply chains (Heckmann et al., 2015). Multimodal maritime supply chains are complex, dynamic systems where the sources and impacts of risk can vary greatly. Scholars in the field have noticed

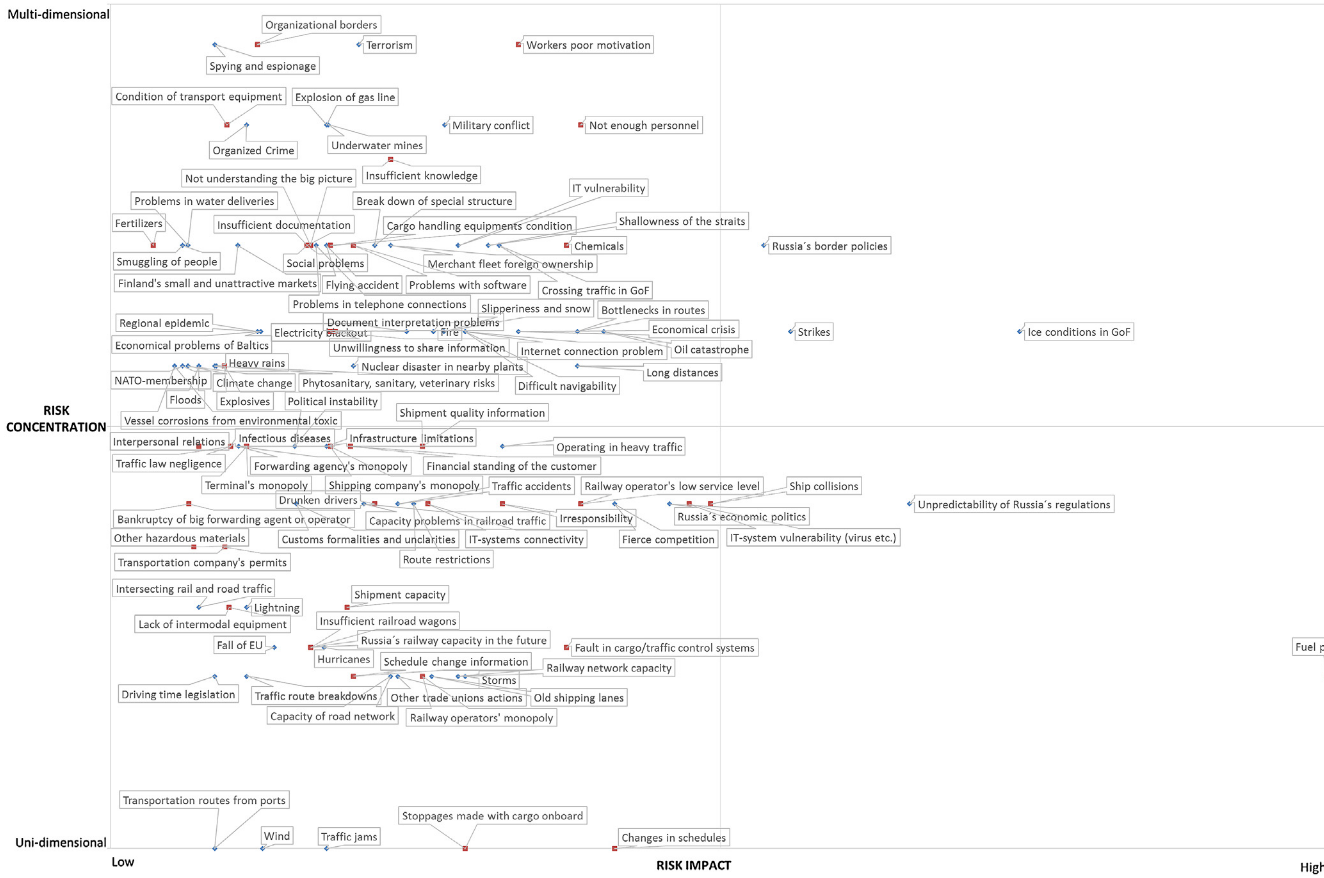

Fig. 2. Illustration of the risk impact (x-axis), concentration (y-axis), and endogenous risks (red)/exogenous risks (blue).

the challenges in managing maritime logistics and do advocate for integration between members of the supply chain (e.g. Kwesi-Buor et al., 2016; Tran et al., 2011; Bichou and Gray, 2004). Our proposed measurements account for the characteristics of the multimodal maritime supply chain and different actors' risk management abilities regarding different sources and their impacts.

As an additional finding, our study shows why and how collaboration is important in the supply chain context, as the visibility of the risks and their control mechanisms do not necessarily reside within the same company. In such cases, applying a holistic risk management strategy benefits the focal firm as well as the whole network in that the visibility of the supply chain could also enable effective management at the process level. In this regard, our results support the findings of Mason et al. (2007), who suggest that combining vertical and horizontal collaboration is extremely beneficial in optimising transport solutions. More broadly, they confirm the importance of both vertical and horizontal collaboration in various types of supply chains and value networks (Möller and Rajala, 2007; Ritala et al., 2009; Van Veen-Dirks, 2006). It has also been suggested that lowering supply chain risks facilitates inter-organisational trust and thus further increases the benefits of collaboration (Laeequddin et al., 2009). Furthermore, by applying the systems approach, our results address the gaps Hughes et al. (2015) and Read et al. (2013) point out. This can help identify the dynamic aspects of a system. By utilising systems models, this study can help companies understand and develop maritime supply chain systems to ensure more effective risk management practices.

5.2. Implications for practice

The results of our study provide several implications for managerial practices in the realms of supply chain and risk management. First, our analysis divided the risks according to their sources (e.g. endogenous or exogenous) as well as the nature of their impact (e.g. costs, quality and time delays). Analysing risk visibility and controllability over these issues helps managers allocate their attention to the most relevant and impactful risks as well as to the parts of the supply chain where more attention is needed. Second, the frameworks utilised here help to analytically simplify and address complex risk management issues. For instance, the matrix-type approach to analysing risk impact and dispersion introduced here could help in visualising the most impactful and hard-to-manage risks. This, in turn, could help supply chain managers focus their efforts where they are most needed. Third, our results indicate that there is a strong case for collaboration across supply chain actors. The visibility and controllability of risks varies considerably across different actors, and integrating these insights between them could result in better overall system-level risk management. Even though some actors emphasised the differences between the businesses in the supply chain, the actors are often in unique positions and possess unique risk management capabilities that enable them to identify and analyse risks in new ways—especially when the insights are integrated. There are challenges, however, in the collaborative approach. Some of our participant companies attempted to engage in collaboration, for example, but a lack of trust seemed to prevent a deeper involvement than what was strictly necessary. This inhibited extensive co-operation and information sharing. A deeper understanding of the dynamics and benefits of actor collaboration would enhance supply chain risk management.

6. Conclusion

In this study, we analysed maritime supply chain risks using a systematic approach to evaluate controllability and visibility. The results show that endogenous and exogenous risks are dispersed across the supply chain, and their controllability and visibility vary significantly between the supply chain actors. Thus, collaboration, communication and a systematic approach to risk management are essential in dealing with such risks. Overall, we believe the systematic approach—as developed in this study—is useful in understanding and managing complex multimodal supply chains.

This study's qualitative and explorative nature has limitations. The risk assessment is based on the experiences of one specific supply chain, and the expert panel used in the constructive validation and risk management ability assessment represents the subjective views of the experts in question. Furthermore, given the background of the interviewees, there may have been a lack of conceptual clarity regarding risk and its sources and drivers. This was taken into consideration: the interviewees responded with tales of cause and effect. In this respect, the findings are in line with earlier studies (e.g. Peck, 2005; Zsidisin, 2003), which state that practitioners perceive risk as a multidimensional construct. For instance, the lower-in-the-hierarchy trucking companies seemed to only have vague ideas about their functions in the supply chain and how a disruption would affect it. Typically, their perspectives were narrow, single-functioned and logistics-based. When considering the connection between organisational policy and safety culture (e.g. Underwood and Waterson, 2013), it can be argued that the organisations that neglect to share essential risk information can severely undermine the entire supply chain's risk management abilities.

To overcome the limitations of the current study, further qualitative and quantitative studies are needed to deepen and generalise our findings. Limitations include the unique perspective of different respondents with respect to their background and organisational objectives, which should be taken into account when interpreting the results. Indeed, as organisations from different fields and ownerships were the source of information, the scores and opinions will likely differ. We believe, however, that the results provide a useful point of departure for future research. For instance, the risk-analysis tools introduced here could be used as a platform for survey studies in which the categorisation of different types of risk—in terms of impact and dispersion—would facilitate the exploration of the most suitable and popular management mechanisms. The tools and frameworks developed in this study, along with the results, provide many opportunities for further research to analyse risk systematically.

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