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Information-Exchange Vulnerability in Supply Chains

ความเปราะบางของการแลกเปลี่ยนข้อมูลในโซ่อุปทาน

ABSTRACT

Dependency on accurate and timeliness information is increasing in supply chains, and disruption in information exchange can cause severe repercussions to the flow of materials. In addressing the problem this paper assesses the methods of information exchange used and their respective disruption risks in the wood supply chains of an international pulp and paper manufacturer. The study is based on qualitative interviews and Internet-based questionnaire responses from employees engaged in logistics management in the supply chains in question. The main risk identified arises from information-intensive logistics systems. Internet and telephone connections as well as personal relations are considered essential for fluent information exchange.

Keywords: Supply chain; Information-exchange methods; Disruptions; Risks; Wood supply chain; Forest industry.

Information-Exchange Vulnerability *in Supply Chains*

บทคัดย่อ

ข้อมูลข่าวสารที่ถูกต้องแม่นยำและทันสมัยมีบทบาทสำคัญต่อการจัดการโซ่อุปทาน การหยุดชะงักของการแลกเปลี่ยนข้อมูลสามารถสร้างผลกระทบในเชิงลบต่อกระบวนการไหลของสินค้าได้ ดังนั้น บทความนี้จึงมีวัตถุประสงค์ในการประเมินวิธีการแลกเปลี่ยนข้อมูลและความเสี่ยงจากการหยุดชะงักในโซ่อุปทานของอุตสาหกรรมการผลิตเนื้อไม้และกระดาษ การศึกษาใช้การสัมภาษณ์เพื่อให้ได้ข้อมูลเชิงคุณภาพ ร่วมกับการใช้แบบสอบถามผ่านทางอินเตอร์เน็ตเพื่อเก็บข้อมูลจากเจ้าหน้าที่ที่เกี่ยวข้องกับการจัดการโลจิสติกส์ภายในโซ่อุปทานที่ศึกษา ผลการศึกษาพบว่า ความเสี่ยงหลักเกิดจากการมีข้อมูลมากมายอยู่ในระบบโลจิสติกส์ นอกจากนี้ การเชื่อมโยงของระบบอินเตอร์เน็ตและโทรศัพท์ รวมถึงความสัมพันธ์ส่วนบุคคลก็ส่งผลต่อการลื่นไหลของการแลกเปลี่ยนข้อมูล

คำสำคัญ : โซ่อุปทาน วิธีการแลกเปลี่ยนข้อมูล การหยุดชะงัก ความเสี่ยง อุตสาหกรรมไม้

INTRODUCTION

Supply chains are becoming increasingly long, generating a complex matrix requiring highly coordinated flows of goods, services, information and money across national boundaries (Giannakis and Louis, 2010; Mentzer et al., 2001). There are several drivers causing the various functions of the supply chain to be divided among a growing number of actors, which decentralizes the knowledge embedded in it. The result is a decrease in knowledge about what goes on beyond the companies' own functions, and an increase in dependency on information exchange between those in the chain.

Supply-chain disruptions have become a significant issue for many companies, and managing them is likely to play an increasingly important strategic role (Reyes et al., 2009). According to Jttner (2005), a disruption affecting an entity anywhere in the chain can have a direct effect on a corporation's ability to continue operations. The vulnerability of one actor, due to a lack of information for example, exposes the whole chain to various risks. Hence, it is important to investigate cross-border supply chains in the search for and implementation of risk-management strategies (Manuj and Mentzer, 2008). Investor reactions to supply-chain disruptions are clearly of significance in that firms admitting to major problems have seen their shareholder value drop by approximately 10 per cent on average (Handfield and McCormack, 2008; Hendricks and Singhal, 2003). This illustrates the effects that disruptions can have.

New methods of information exchange (e.g., ICT and mobile solutions) help to reduce these deficiencies. However, the increasing use of these new systems leads to dependency on them, bringing further vulnerabilities to the supply chain (Christopher and Lee, 2004). Despite the increased awareness of supply-chain vulnerability and risks among practitioners, the concepts are still in their infancy, and research has shown that most organizations are poorly prepared in terms of managing the risks (Jttner, 2005; Manuj and Mentzer, 2008). The focus in recent scientific publications in the field has been on the need for a systematic analysis of supply-chain vulnerability (i.e. Peck et al., 2003; Waters, 2007).

The forest industry has an important position in Finland, accounting for approximately 19 per cent of export trade values. In terms of land logistics, every third large or medium-sized truck serves the forest industry (Rumpunen, 2010). The supply chains serving the industry belong to complicated international supply networks, and there is a need for constant information exchange to ensure the undisrupted flow of materials. Given the ever-increasing competition in the field, the value of the information exchange among the growing numbers of actors involved within these networks is also increasing. Wood-supply networks in Finland are both regional and international, serving competing mills and competing organizations at the same time, and indeed the whole industry. One of the sources of wood supply for the Finnish forest industry is the Baltic States.

The main aim in this paper is to contribute to the current literature on supply-chain risk management by illustrating the vulnerabilities inherent in the methods of information exchange used in the wood supply chain of a South East Finnish forestry company. The first task was to carry out a review of supply-chain processes and methods of information exchange. Three types of supply chain were identified, employing different transport modes. The multimodal international maritime supply chain was chosen for closer study. The investigation

focused on the purposes of the different information-exchange methods in order to pinpoint the operations that would be affected in case of a disruption. Finally, a risk matrix was created in order to assess the risk involved in each method. The study is based on the literature on information exchange, information quality and supply chain risk management, as well as on the empirical findings from the interviews and questionnaires.

The paper continues with a brief introduction of the main concepts, namely supply chain risk, information exchange and supply chain risk management. The empirical part of the study begins with a description of the research methods, the case supply chains, and the information-exchange methods used. The findings from the interviews are reported and the risks related to information-exchange are assessed. Finally, the findings are discussed and the conclusions presented.

SUPPLY CHAIN RISKS AND INFORMATION EXCHANGE

The theoretical part of this paper describes the main concepts in accordance with the state-of-the-art literature. Definitions of supply chain and risk are given, and their management is discussed. The focus then shifts to the concept of supply chain risk management, and the role of information exchange in it.

According to Minahan (2005), the strategic role of supply management is becoming stronger, and its operations make a notable contribution in terms of value across organizations. A supply chain is defined as a system of suppliers, manufacturers, distributors, retailers and customers in which material, financial and information flows connect participants in both directions (Fiala, 2004). The holistic and strategic approach to operations, materials and logistics management is commonly referred to as supply chain management (SCM) (Tan, 2001). According to Lysons and Farrington (2006), there is no single and unique definition of supply chain management, which could be considered a management philosophy, the implementation of a management philosophy, or a management process.

Academics and professionals define risk in many ways, depending on the discipline and the context. According to Paulsson (2004), risk is an event with negative consequences, or entailing “the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge”. It is also associated with unreliable and uncertain resources causing interruption in the supply chain (Tang and Musa, 2010). Risk is defined in this study as the potential occurrence of an incident or failure that inhibits the free and undisrupted flow of supply-chain material and information, thereby causing interruption (Tang and Musa, 2010; Waters, 2007).

A standard formula for the quantitative definition of supply chain risk is:

$$Risk = P(Probability) * I(Impact)$$

The risk is thus defined as the product of the probability (P) of loss times the significance of its consequences (I) (Mentzer et al., 2001).

According to Thun and Henig (2011), internal supply chain risks are assumed to have a higher occurrence probability than external risks in that the majority of the external risks are highly exceptional whereas internal risks cannot be considered uncommon. Furthermore, external risks have a higher impact because their occurrence normally has severe consequences. External risks are those that are linked to environmental (storms, floods), economic (strikes), political (wars, embargoes) and social causes, whereas internal risks arise from interactions between organizations in the supply chain. (Lysons and Farrington, 2006.) According to the Cranfield University report (2002), there are five types of supply chain risks: lack of ownership, chaos risks, decision risks, JIT-related (JIT = just in time) risks and inertia risks.

Risks can be evaluated on two dimensions, 'probability' and 'impact', based on a Likert scale. A risk-assessment tool giving a clear and holistic picture of risks along both dimensions is the risk-probability-impact matrix, as shown in Figure 1 below. The tool allows easy categorization onto different risk levels, and therefore facilitates their analysis and management. (Thun and Henig, 2011).

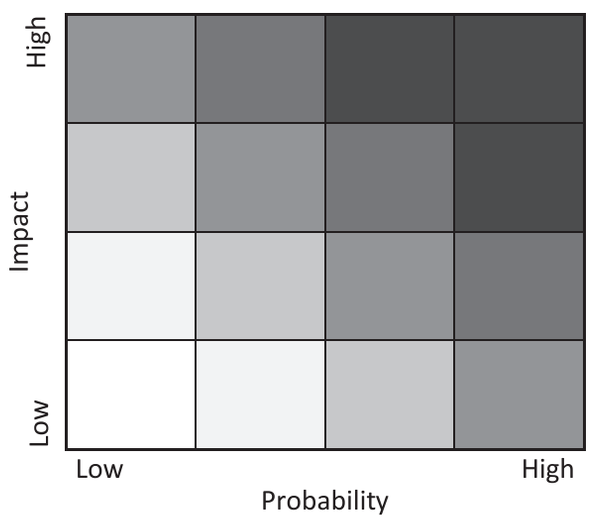

Figure 1: The risk matrix
(Adapted from Norrman and Lindroth, 2002; Thun and Henig, 2011)

Risk management is the function responsible for managing risks in organizations. This means taking actions that reduce the consequences or probability of the unwanted occurrence or failure. Risk management could also be defined as: "to take actions to shift the odds in your favor" (Paulsson, 2004; The Royal Society, 1992).

Supply chain risk management means dealing with risks and uncertainties caused by, or impacting on, logistics-related activities or resources. It is carried out collaboratively among partners in a supply chain through the application of risk-management-process tools (Paulsson, 2004, Norrman and Lindroth, 2002). The process starts with the identification and computation of probable risks and their possible impact on operations in the supply system. Identifying the possible risks in the supply chain is essential, and is a key risk-management activity (Giannakis and Louis, 2010).

Information-Exchange Vulnerability *in Supply Chains*

According to Minahan (2005), the success of supply management depends heavily on the ability to access, organize, analyse and utilize data. Information has become a key driver for improving supply-chain performance through the better matching of supply with demand. Information exchange in the supply chain depends on the extent to which information is communicated between the partners. In terms of facilitating dynamic actions and decision-making, information exchange and information quality strongly affect coordination operations within supply chains (Li and Lin, 2006; Fiala, 2004). Information exchange is a tool for making available undistorted and up-to-date data at every step in the process, and for dealing with problems such as supply uncertainty (Fiala, 2004). By making the data available and sharing it with other parties within the supply chain an organization can speed up the information flow, improve its efficiency and effectiveness, and respond more quickly to changing customer needs (Fu and Zhu, 2009).

Information overflow may be harmful however, and although it is important to share information in the supply chain, the quality (what, when, how and with whom) of the information exchanged matters even more. Information quality is defined as "the degree to which the information meets the needs of the organization" (Monczka et al., 1998; Forrester, 1962). According to Li and Lin (2006), it includes aspects such as accuracy, timeliness, adequacy and credibility, and Monczka (1998) adds completeness and compatibility across all users. When organizations have timely and accurate information at their disposal they are better able to cope with the various uncertainties in the supply chain (Ryu et al., 2009).

Liebeskind (1996) defines knowledge as 'valuable information whose validity has been established through tests of proof, and therefore is distinguished from opinion, speculation, beliefs, or other types of unproven information'. Given that knowledge is acknowledged to be an organizational resource, there is also interest in information systems, called knowledge management systems (KMS). The objective of these systems is to support knowledge creation, transfer and application in organizations. IT tools play a significant role in organizational knowledge-management processes (Alavi and Leidner, 2001).

Advanced information technologies (IT) such as the Internet, intranets, extranets and data warehouses assume major importance in the context of the knowledge-based view of the firm, facilitating the management of large-scale intra- and inter-firm knowledge. Therefore advances in communication and information technologies have great potential (Alavi and Leidner, 2001). The use of the Internet and enterprise resource planning solutions has also reduced the incidence of inaccuracy and redundancy. The widespread use of these systems has further consequences, however, in the form of information disruption (Tang and Musa, 2010).

EMPIRICAL CASE STUDY AND METHODS

This study followed a two-stage research process, the first stage of which was to gather data in qualitative interviews with people responsible for logistics-related tasks (Yin, 1989). The data for the second stage was obtained from an Internet-based questionnaire designed to expand and verify the interview data. The focus of the study was on the supply chains of an international forestry products company's responsible for moving wood within and to South East Finland.

The first-stage interviews were conducted with twelve persons from the supply chains in question. A wide perspective on supply-chain operations and information exchange was considered essential in order to obtain an accurate analysis, therefore the chosen interviewees all had responsible positions in logistics operations and management, terminal operations and procurement. The interviews were semi-structured, discursive, and explorative in nature. The themes and questions were discussed at random in order to encourage a natural conversational style and allow the lead of the interviewees to be followed. All the interviews were conducted on a face-to-face basis and lasted approximately two hours. They were recorded and the audio files were then transcribed to text files, and finally analysed. At the beginning of each interview the interviewee was promised anonymity, and permission to use a recorder was solicited. The interviewees were asked to describe their own activities in the supply chains in question, and to take into account the processes in a broader sense. The aim of the study was to examine the process in order to determine what factors influenced information exchange and information disruption. The systematic research produced an understanding of the case supply chains, including the possible risks and consequences of information disruption. The research method allowed the mapping of the processes under study, and of the factors that matter in information exchange. It appeared in the early phase of the interview process that the maritime supply chain was the most sensitive to information-exchange disruptions with its multimodal phases, and therefore its methods were analysed further in the second questionnaire-based stage. The interview questions were adjusted during the research process as understanding of the issues under scrutiny increased. A closer examination of the supply chain was carried out in order to establish the purposes for which the different methods were used, and eventually to assess the possible information-disruption risks attached to them. An FMEA (Failure Mode and Effect Analysis) framework was used in assessing the scale and causalities of the risks because it seemed to be effective in clarifying the concept of risk in the minds of the interviewees, and in fostering understanding of the causalities.

The interviews gave a holistic view of information exchange in the supply chains. During the second stage of the research process an Internet-based questionnaire was used to verify the results, thus giving a deeper understanding of their significance and the risks involved from the perspective of the whole chain. The questionnaire was based on Webropol software, and was sent to the individuals involved in the maritime supply chain to be further studied, accounting for nine of the twelve interviewees. It comprised seven questions (of which four were multiple choice) formulated on the basis of the findings from the face-to-face interviews. The intention was to elicit more specific information on some of the questions asked in the interviews, and to quantify some of the data in order to establish a between-factor hierarchy. In order to take into account the information that may have been missed in the face-to-face interviews or excluded due to the necessary narrowing down of the questions, the respondents were given the opportunity to write additional comments. If they had further questions or needed clarification email and telephone communication were used.

IDENTIFIED SUPPLY-CHAIN PROCESSES

In order to gain a systematic understanding of the supply chains, step-by-step process maps were constructed based on the interviewees' descriptions. These maps allowed deeper operational-level examination without diminishing the holistic understanding of the overall process. Three processes typically used in the wood

supply chain were identified from the interviews. The first of these concerned an international inter-modal maritime supply chain in the Baltic Sea Region (Figure 2), the second mainly comprised rail transportation from Russia (Figure 3), and the third involved, both regional and international road transport (Figure 4).

The left-hand side of Figures 2, 3 and 4 list the organizations, or their different departments, and the right-hand column shows the main functions of the supply chain. In order to ensure the anonymity of the interviewees and companies the names are not mentioned in this report.

The three supply chains in question were found to be equally important to the case company. However the nature of each chain varied substantially. The maritime chain turned out to be the most economical delivery method in terms of cost. The raw-material quantities per vessel were significantly larger compared with rail and road transport: one vessel could deliver between 4,000 and 5,000 cubic metres of raw material at a time. According to the interviewees, the scheduling of the vessels and the predictability of their arrival times were challenging, but still manageable. The arrival frequency varied a lot: typically the vessels were scheduled to arrive sparsely and frequently, but occasionally there were peaks when several ships came in at the same time. The maritime supply chain, which was international, had a higher number of process phases than the road and rail supply chains, but one of the disadvantages was that deliveries could become difficult or even stop during the winter months. The winter conditions in the Baltic Sea and the closing of the Saimaa Canal from December to February limited vessel deliveries significantly.

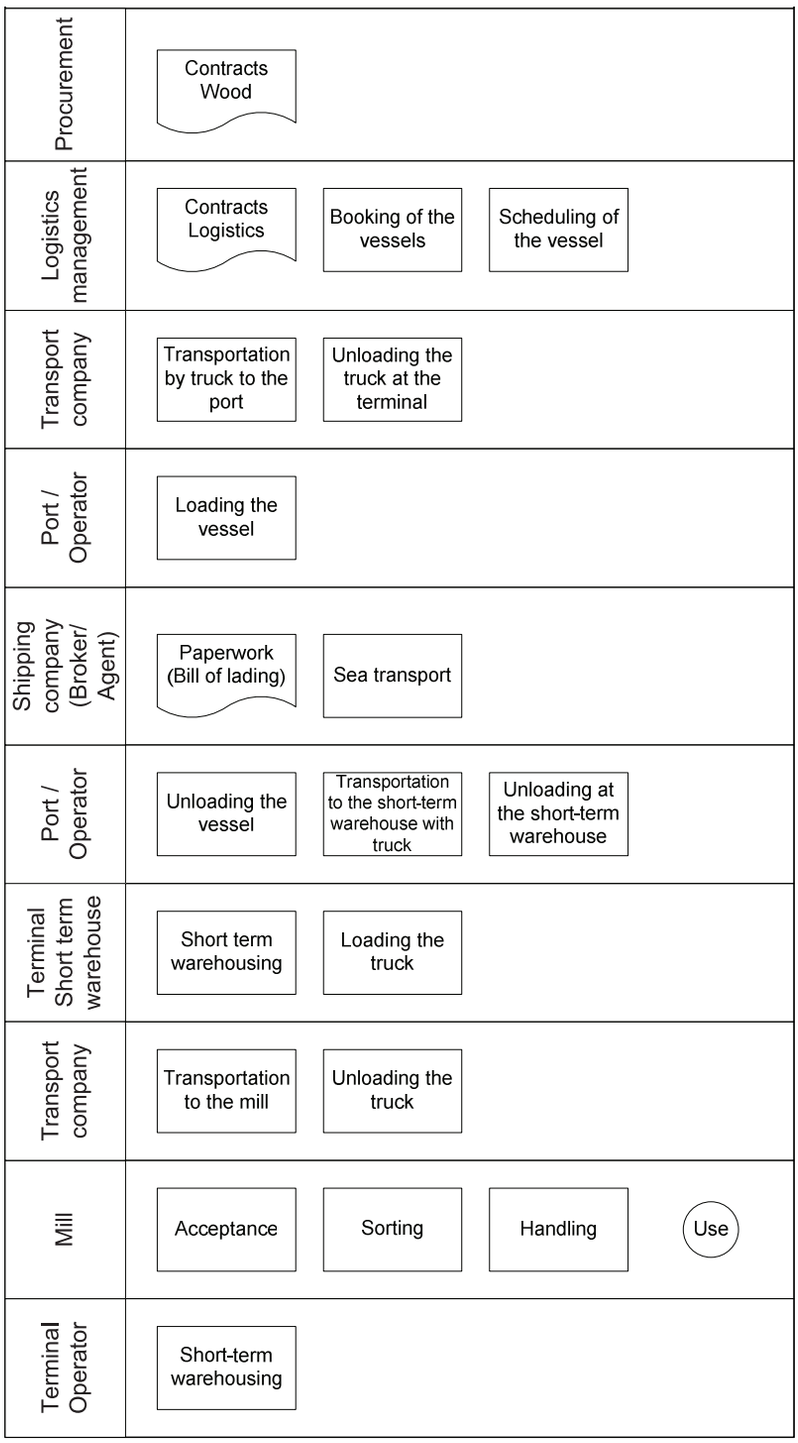

Figure 2: The maritime supply chain

The second of the supply chains under study involved international rail transport (Figure 3), and was more straightforward and involved fewer phases than the maritime chain. The predictability of train arrivals, their frequency and schedules were considered better than in the maritime chain, but worse than in road transport. The quantities of raw materials per wagon and per train were far smaller than per vessel, but considerably more than per truck. In terms of raw-material deliveries by rail, the lack of up-to-date delivery information (schedules, quantities, even assortments) from Russia appeared to complicate the mills production planning and scheduling.

Information-Exchange Vulnerability *in Supply Chains*

The rail supply chain in question incorporated many phases in three different organizations. It appeared from the interviews that organizational borders and even interpersonal relations had a big effect on information exchange in terms of how well information about schedules, quantities and assortments is forwarded in the chain. Overall, the international aspects seemed to increase the challenges compared to domestic transportation. Even though there seemed to be some desire to increase rail deliveries in the future, the limited number of wagons and track capacity will restrict development and growth in this area.

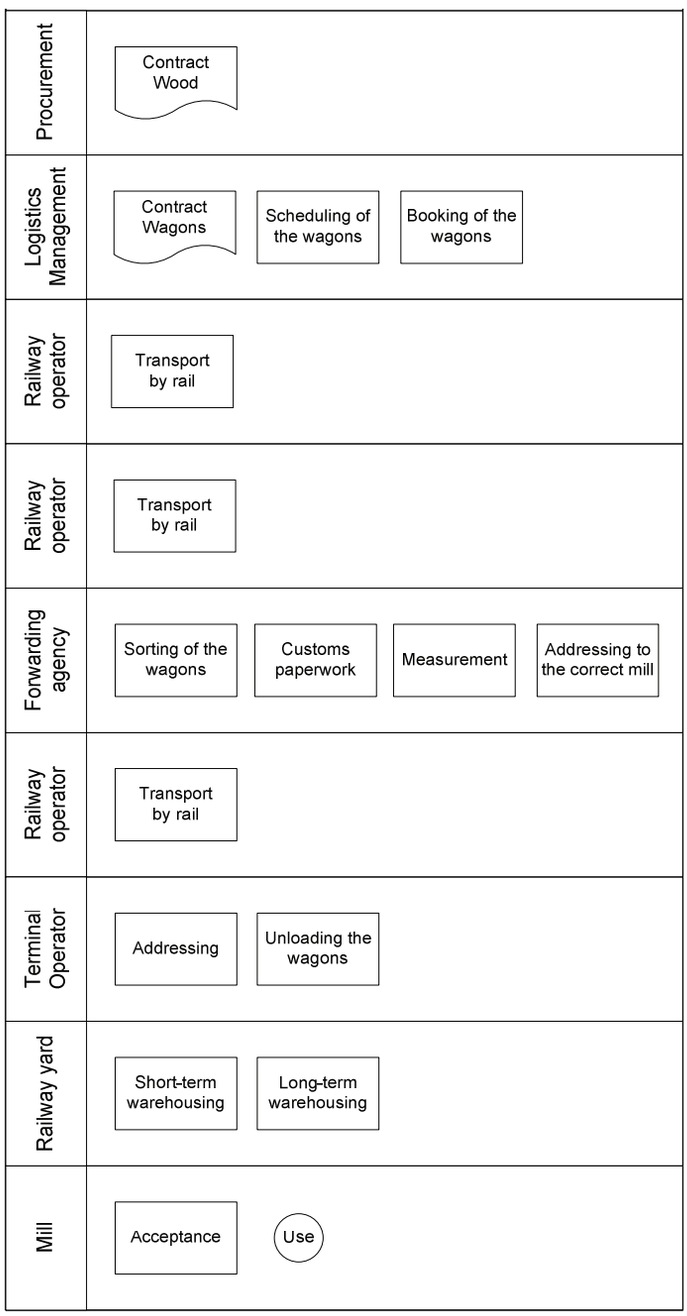

Figure 3: The rail supply chain.

The deliveries made by road (Figure 4) were typically regional and from areas near the mills. Both domestic and international (Russia) deliveries were used. Of the supply chains under scrutiny, the road transport chain was considered the most flexible. It was useful in that it allowed the mills to compensate for the unpredictable schedule changes in vessel and rail deliveries and thus to keep smaller stocks in the mills. The second advantage was the capacity of the trucks: the number of trucks was large enough, and the loading and unloading were not confined to specific areas or schedules.

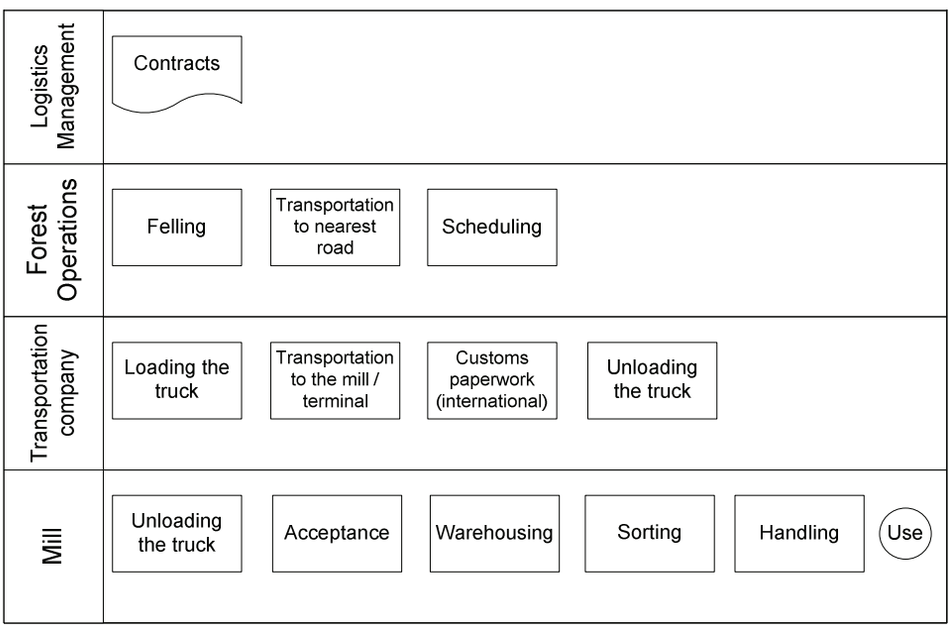

Figure 4: The road supply chain

In the supply chains in question, the information exchange in domestic road transport was considered the most straightforward. In the case of international deliveries on the other hand, predictability was considered to be quite poor because of the customs formalities at the border and the actions of the transportation companies. According to the interviewees, one of the disadvantages of road transport was the period of frost damaged roads (autumn and spring), when deliveries from the forest are severely limited.

METHODS OF INFORMATION EXCHANGE

The interviewees had different opinions about the importance of different information-exchange methods. Typically, the one they considered most important was the Sea logistic system, which gives information not only about the logistics operations, but also about many related issues. Email, the telephone, planning and sales system 6 were mentioned in most of the interviews. The questionnaire helped to clarify this matter and to give a holistic view of the importance of different systems from the perspective of the whole supply chain. Table 1 lists the methods used, describes each one and gives the importance score obtained from the questionnaire. For confidentiality reasons the system names are not revealed.

Information-Exchange Vulnerability *in Supply Chains*

In order to shed light on the hierarchical relations between the information-exchange methods and the importance of each one in the case maritime supply chain, the questionnaire items were coded as follows; 0 = not used, 1 = very low, 2 = low, 3 = high, and 4 = very high. According to the findings, the most important method was the sea logistics system. Telephone and email were also considered very important, whereas the logistics system for planning and operating and Planning and sales system 6 were not so important, but still significant. The role of coffee-table discussions and face-to-face meetings was also notable, but other information-exchange methods had a more modest role.

Table 1: Methods of information exchange

Information exchange method	Description	Importance in the case SC
Bookkeeping system 1	Invoice handling, payment data and financial reporting	0
Bookkeeping system 2	Invoice handling	0
Bookkeeping system 3	Invoice handling and financial reporting	1.00
Coffee-table discussions and their own network	Discussions with colleagues; a social network of colleagues and partners	2.33
Communication Applications	The organizations internal instant messaging system	1.33
EDI Messages	Electronic Data Interchange -messages, structured data transmissions between organizations by electronic means	0
E-mail	Bookings, information concerning raw-material demands, changes in schedules, raw-material quality and assortments	3.33
Fax	Confirmations, wagon data from Russia	1.00
Logistics system (planning and operating)	Planned and delivered volumes, and freight contracts: rail, truck and vessel deliveries	2.67
Logistics system (planning)	Planned and delivered volumes, and invoice handling: rail, truck and vessel deliveries	1.33
Logistics system (sea logistics)	Planned and delivered volumes, schedules, quality, assortment and destination information and also freight contracts: vessel deliveries	4.00
Meetings (face-to-face and group phone)	Group phone meetings weekly or monthly, face-to-face meetings when needed	2.67
Office applications	Excel, Word and PowerPoint	1.67
Phone	Problem solving and double-checking	3.33
Planning and sales system 1	Mill(s) system including planned volumes, orders and schedules	0.33
Planning and sales system 2	Mills system including planned volumes, orders and schedules	0.33
Planning and sales system 3	Invoicing information and mills production programmes and plans	0
Planning and sales system 4	Invoicing information and mills production programmes and plans	0
Planning and sales system 5	Corporation-level information on all planned raw-material volumes globally	1.00

Table 1: Methods of information exchange (Continue)

Information exchange method	Description	Importance in the case SC
Planning and sales system 6	Bookkeeping, planned and delivered volumes: rail, truck and vessel deliveries	2.67
Planning and sales system 7	Product and sales information: quantities, prices, invoices and loading orders	0
Planning and sales system 8	Information about planned and delivered volumes, payments and freight contracts: rail, truck and vessel deliveries	1.33
Reporting system	Mills reporting system	0

One surprising discovery was that in case of sudden changes the relative importance of the systems changed. The information systems were not very capable of handling sudden changes, and matters were typically resolved primarily by telephone or email. Thus the relative importance of these forms of communication was higher in conditions of change or high uncertainty. The significance of personal knowledge was surprisingly high, according to the interviewees. In their view, the tacit knowledge gained through long work experience in the supply chain was highly important, and its value should not be overlooked.

The interviews revealed the use of the following information-exchange methods:

- o Acquiring background information
- o Making bookings (truck, vessel, wagon)
- o Making changes
- o Issuing confirmations
- o Having discussions/negotiations
- o Improving/developing things
- o Meetings
- o Planning
- o Scheduling

The questionnaire contained items aimed at finding out which of the methods mentioned were used for the various purposes. Table 2 summarises the responses, thereby also revealing the vulnerabilities in the event of disruption in a particular form of information exchange. According to the responses, *E-mail* (18.8% of all usage), *Telephone* (16.7%) and *Face-to-face meetings* (17.4%) were clearly the most widely used methods in all of the given functions. They seemed to be the most flexible in all of the operations as well. The popularity of the more personal methods highlights the need for human involvement in managing the operations, as well as the social skills of individuals working with wood supply chains. Of the methods adopted in the supply chain the sea logistics system seemed to be the most versatile in that it was used for six of the nine functions in question. Some of the methods did not have a clear role in the maritime supply chain, and others (e.g., Fax, *Planning and Sales systems 1*, *2* and *5*) had only one specific function. Curiously enough, the *Logistics system (planning and*

operating) did not appear to have any role in the *planning* function. It was the same in some of the *Planning and sales systems*, but this may be attributable to the fact that some of the systems did not have an essential role in the operations of the maritime supply chains. Overall, the results were surprising given the importance ratings listed in Table 1. However, it is worth noting that the usage part of the questionnaire did not elicit the extent to which the individual actors used the different systems, only asking them to indicate whether they used the particular system in the given operations or not. In other words, how much of the overall operations a particular system covered remained unclear.

The most frequently mentioned use of the information was for *acquiring background information* (counting 18.8% of the total). *Planning* (14.6%), *issuing confirmations* (13.9%) and *scheduling* (13.9%) were also used a lot, whereas using it for *making bookings* (6.3%), *making changes* (6.9%), *meetings* (6.9%) and *improving/developing things* (7.6%) was far less frequent. The respondents were given the opportunity to state whether they used any additional methods, or used the given methods for other purposes than those listed in the questionnaire, but nothing was noted.

Table 2: The usage of information-exchange methods in the supply chain

	Acquiring background information	Making bookings (truck, vessel, wagon)	Making changes	Issuing confirmations	Having discussions / negotiations	Improving / developing things	For meetings	Planning	Scheduling	TOTAL	
Bookkeeping system 1	1	0	0	0	0	0	0	0	0	**1**	0.7%
Bookkeeping system 2	0	0	0	0	0	0	0	0	0	**0**	0.0%
Bookkeeping system 3	0	0	0	0	0	0	0	0	0	**0**	0.0%
Coffee-table discussions and their own network	4	1	0	2	3	2	2	3	1	**18**	12.5%
Communications applications	2	0	1	2	2	0	1	0	0	**8**	5.6%
EDI-messages	0	0	0	0	0	0	0	0	0	**0**	0.0%
E-mail	5	2	3	4	3	3	1	2	4	**27**	18.8%
Fax	0	0	1	0	0	0	0	0	0	**1**	0.7%
Logistics system (sea logistics)	2	1	1	2	0	0	0	2	3	**11**	7.6%
Logistics system (planning and operating)	1	0	0	1	0	0	0	0	2	**4**	2.8%
Logistics system (planning)	0	0	0	1	0	0	0	1	1	**3**	2.1%
Meetings (face-to-face and phone meetings)	4	1	1	1	4	3	4	5	2	**25**	17.4%
Office applications	1	0	0	1	1	1	0	4	1	**9**	6.3%
Phone	4	2	3	3	3	2	2	2	3	**24**	16.7%
Planning and sales system 1	0	1	0	0	0	0	0	0	0	**1**	0.7%
Planning and sales system 2	0	1	0	0	0	0	0	0	0	**1**	0.7%
Planning and sales system 3	0	0	0	0	0	0	0	0	0	**0**	0.0%
Planning and sales system 4	0	0	0	0	0	0	0	0	0	**0**	0.0%
Planning and sales system 5	0	0	0	0	0	0	0	0	1	**1**	0.7%
Planning and sales system 6	2	0	0	1	0	0	0	1	1	**5**	3.5%

Table 2: The usage of information-exchange methods in the supply chain (Continue)

	Acquiring background information	Making bookings (truck, vessel, wagon)	Making changes	Issuing confirmations	Having discussions / negotiations	Improving / developing things	For meetings	Planning	Scheduling	TOTAL	
Planning and sales system 7	0	0	0	0	0	0	0	0	0	**0**	0.0%
Planning and sales system 8	1	0	0	2	0	0	0	1	1	**5**	3.5%
Reporting system	0	0	0	0	0	0	0	0	0	**0**	0.0%
TOTAL	**27**	**9**	**10**	**20**	**16**	**11**	**10**	**21**	**20**	**144**	
	18.8%	6.3%	6.9%	13.9%	11.1%	7.6%	6.9%	14.6%	13.9%		100%

A RISK ANALYSIS OF INFORMATION EXCHANGE IN THE SUPPLY CHAIN

The supply chain under investigation had a logistics planning system that was used by most of its actors. However the interviewees mentioned that this system did not always give correct information concerning the quality, volumes, wood assortment and destinations. There are many reasons behind the risks related to information accuracy. The interviewees mentioned in particular the lack of system integration. The logistics, procurement and mills systems did not have a common connection, and if the information is not transferred automatically, the data must be inputted manually into each system.

Given the lack of system integration the human factor seemed to play a major role in the personnels lack of a holistic understanding of the supply chain, hence in the ensuing risks. The employees did not necessarily always understand the “big picture”, or the consequences of their actions. Interpersonal relations were also considered important, and a potential risk in terms of information exchange if the supply-chain actors had poor relations among one another. Ways of maintaining the relationships included keeping in touch, and engaging in light small talk between heavy business matters.

Information about changes in schedules was not always accurate in the logistics system, and the speed of the information flow was not always as high as it should have been. In particular, given the short distances in the Baltic Sea Region, there was a need for very rapid information exchange. The vulnerabilities of an IT-based society were evident in the possible breakdowns in Internet and email connection, which constituted one of the most significant risks. The main logistics sea-transport planning system was Internet-based therefore a secure connection was vital. Organizational borders were also mentioned as potentially causing disruptions in information exchange.

Information-Exchange Vulnerability *in Supply Chains*

Intercultural aspects seemed to have some effect, too. During the course of the study it became apparent that the information input into the system (mainly the Sea logistics system) was lax in the Baltic States. This may be attributable to a poor understanding about who needed the information and why. It was noted during the interviews conducted in the Baltic States that the interviewees were somewhat more suspicious than the interviewees in Finland, and did not seem willing to share as much information about the processes in the supply chain and the information-exchange methods adopted.

The tacit knowledge related to managing complex supply chains was mentioned in several interviews. The knowledge that was essential in order to manage the flows was vulnerable to loss in situations in which the management personnel changed. Some of the interviewees mentioned that it could easily take from one to two years to acquire the level of knowledge required to efficiently manage the operations of the supply chain.

The aspects mentioned above could cause many problems in the supply chain. For example, according to the interviewees the receipt of incorrect or inaccurate information concerning the quality, volumes, wood assortment and destination of raw materials caused general confusion and uncertainty. Extra work, time loss, and especially extra costs for the terminal and the mill were also of great concern. The port and terminal workers are not able plan their working schedules if there is a risk of insufficient storage space or a lack of raw materials.

The second step in the analysis was to assess the disruption-risk factors mentioned by the interviewees in the Internet-based questionnaire in response to items based on the methods identified in the face-to-face interviews. The respondents were asked to describe the probability and impact of disruption in each information-exchange method, and this was coded as: 0 = non-existing, 1 = very low, 2 = low, 3 = high and 4 = very high. The risks were then calculated by multiplying the probability and risk-impact values.

The risk analysis framework as set out in Figure 5 summarizes the results of the risk analysis. It gives a holistic view on the risk of disruption in the supply chain related to information exchange, categorized by each method used. The descriptive, but not explicit, rating of the risks illustrates the risk matrix tool and its feasibility in assessing their effects.

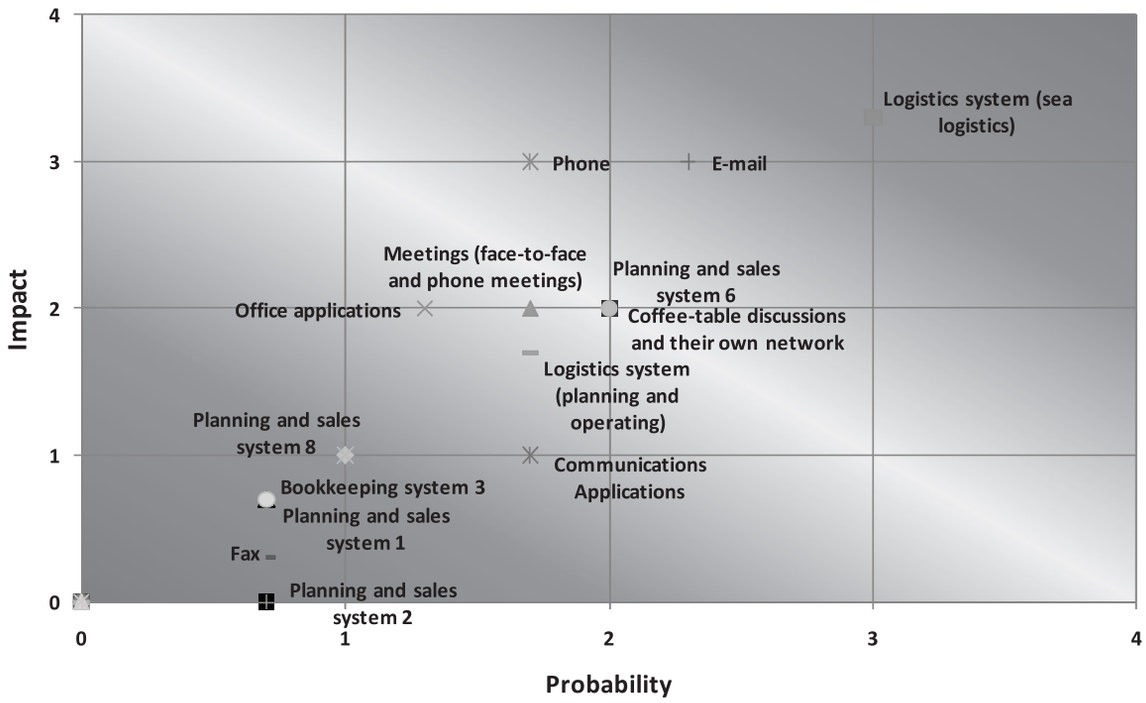

Figure 5: A disruption-risk matrix covering methods of information exchange in supply chains

The more risks involved in the information-exchange system, the closer to the upper-right-hand corner they appear. The highest single disruption risk in the investigated supply chain related to the Logistics system that operated sea traffic (Probability of 3 times the Impact of 3.33 resulting risk rating of 10). Email was given the second highest relative risk rating (7), and the third was the telephone with a relative risk value of 5. The interviewees mentioned both email and the telephone as methods of exchanging new information and solving problems, and therefore it was not surprising that the disruption effects turned out to be rather high. Planning system 6, informal Coffee-table discussions and the interviewees own network of colleagues and partners were all given a relative risk rating of 4, and Meetings, both face-to-face and by telephone a rating of 3.3.

DISCUSSION AND CONCLUSIONS

Supply chains are becoming more and more complex and disintegrated, which causes them to be increasingly dependent on information exchange between the members. Proper information exchange ensures the stable flow of goods and material between growing numbers of actors by enabling better predictability in the supply chain. The risks related to information exchange are severe, and a disruption or a delay could have devastating effects given that schedules in general are being trimmed as much as possible. This paper contributes to the literature in this field in introducing preliminary research concepts aimed at identifying and assessing the importance of information-exchange methods and the associated risks of disruption in supply chains.

Information-Exchange Vulnerability *in Supply Chains*

This systemic study of the supply-chain process identified a number of information-exchange methods, to which the many actors with their different perspectives on the supply chain have different levels of access. Some of the systems seemed to have a broader reach over the whole chain than others: the mills' and the high-level logistics-management systems were beyond the reach of many, for example. The importance of the different methods varied to different extents, as did the purpose for which they were used. Overall, nine different usage categories were identified.

Combining the results of the questionnaire analysis as percentage shares in the same figure (Figure 6) allows comparison of the quantitative results. Given that the risk analysis determines the vulnerabilities of the different information-exchange methods, their relative importance seems to follow somewhat similar lines. Obviously the impact variable of risk value assigns some importance to methods, but as the risk value depends on its likelihood, the implication is that some of the systems rated as important were in fact quite vulnerable. The use of different information systems may be of value in risk management in determining what kind of functions can be affected by disruption in certain information-exchange systems. Some of the methods identified covered multiple functions and seemed to have a strong position in the supply chain. In fact, these methods (E-mail, Telephone and Meetings) had the most important role in the event of sudden changes or disruptions in some of the other systems. As methods of information exchange they also seemed to have the capacity to replace other systems to some extent.

The case analysis revealed that the risks attached to the information-exchange methods varied. The highest risk arose from the sea logistics system, which holds a huge store of information. If it went down, replacing it and still maintaining the same level of efficiency would be an enormous task. Thus, even if one system has broad and powerful coverage, it may constitute a serious risk in terms of "putting all one's eggs into the same basket". The email connections were also considered highly risk-prone in that disruption would clearly hinder the operations. The telephone was used extensively in order to exchange information and to ensure its arrival, maintain good personal connections with the other actors in the supply chain, and most importantly as a solution in extenuating circumstances. Some of the information systems were integrated, and some were seriously lacking in terms of integration. Insufficient methodological integration was mentioned as one of the key problems that led to the use of other methods instead.

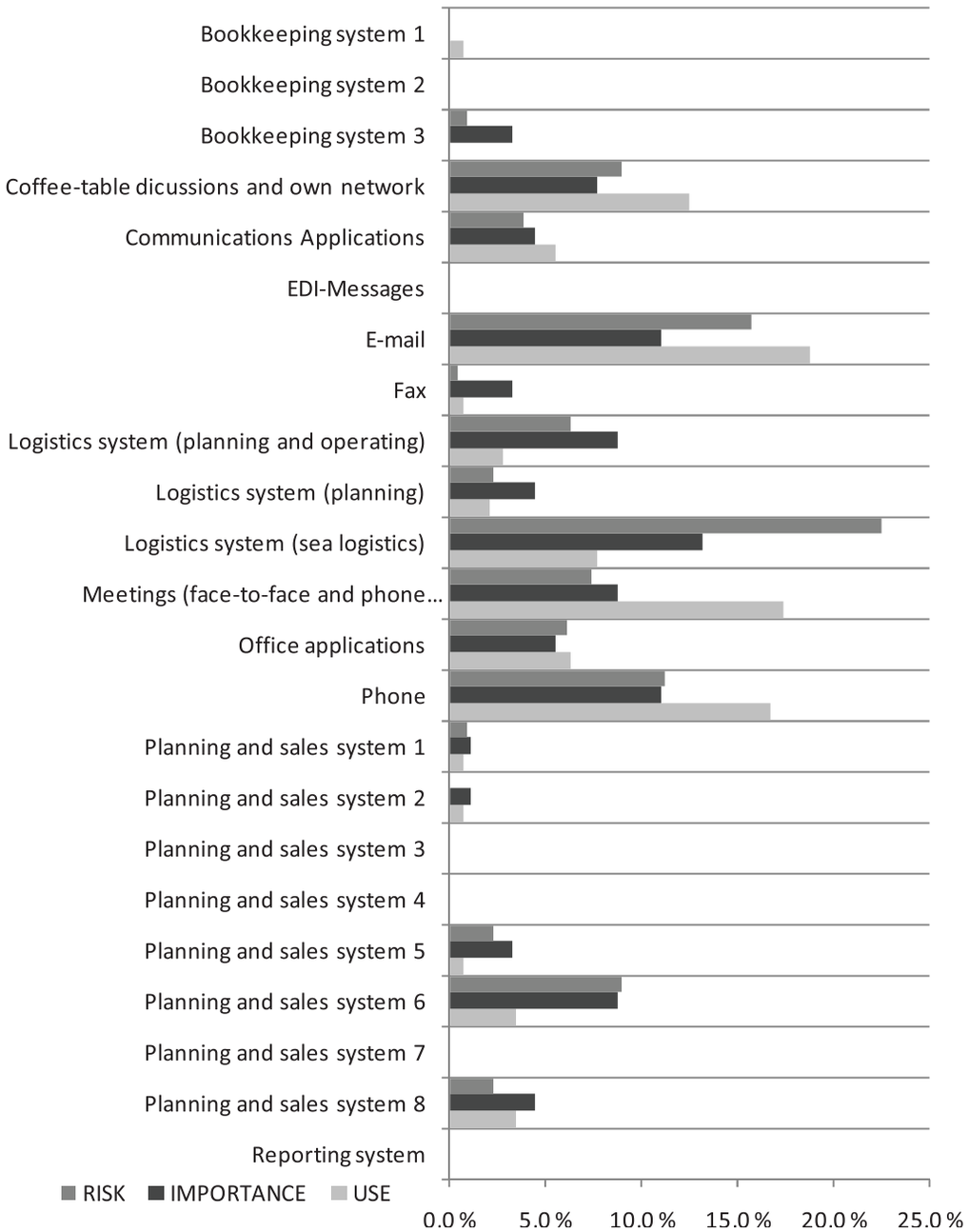

Figure 6: Disruption risk, and the importance and use of information-exchange methods

Apart from the technical risks attached to several of the information-exchange methods, human-related factors played a significant role. Mention was made of deficiencies within the supply chain and in the ability to input information, but correcting input inaccuracy presented its own unique challenges. Moreover, managing the flow appeared to be quite information-intensive. The knowledge acquired through long experience in the operations of the supply chain, combined with a good network of partners, enabled the actors to compensate for possible inaccurate information, thereby emphasizing the significance of system knowledge. These results also reflect some previous findings reported in the scientific literature: according to Argote and Ingram (2000), studies have shown that working together in dyads and small groups improves performance in terms of acquiring

knowledge of who knows what. Research has also shown that the nature of the social ties interacts with the characteristics of the knowledge being transferred and thus affects transfer outcomes. Moreover organizational units can use social networks to link new sources of knowledge and facilitate the interpretation of new knowledge. In this case, too, the interviewees considered the coffee-table discussions, the informal discussions with colleagues and their own network (a social network for colleagues and partners) important in terms of acquiring background information, for example. The results of the study therefore support the findings of both Argote and Ingram (2000) and Argote et al. (2003).

One of the risks most frequently mentioned related to information accuracy. The source of any inaccuracy tended to be at the front of the supply chain if those in charge did not have a clear understanding of the consequences that inaccurate information could have on the system as a whole. As noted above, although deficiencies were noted, improving the input method was challenging. The information needed in the supply chain did not always coincide with the system's capabilities, and as in many other cases, email and the telephone acted as a backup method, thereby creating additional work for the management personnel. Again, this emphasizes the significance of system knowledge. Wong and Acur (2010) lend support to these findings, having found in their research an assumption in the current literature that decision makers are rational, competent and consistent, which may not reflect the reality. In a complex environment such as an international supply chain managers may lack the cognitive capacity to understand the consequences of a particular decision (Heiner, 1983; Senge, 1990).

The case study reported above gives a holistic view of the risks related to information exchange in a wood supply chain. It strengthens some of the findings from earlier research, but also brings out new aspects of risk management in supply chains, particularly with regard to disruptions in information exchange, which still lacks empirical investigation. The research method, which was based on qualitative interviews in which the processes were mapped and the methods of information exchange identified, gives a good basis on which to continue in terms of facilitating a deeper understanding of the research subject and the better focusing of the questionnaire. The questionnaire gave more depth in complementing the otherwise descriptive study with quantitative data. The case study has limitations that should be kept in mind, however: it is limited in terms of generalizability in that the sample was quite small and the data subjective. Hence, further empirical studies should include more extensive data and focus on a different geographical area. It would also be fruitful to calculate and categorize other risks related to information exchange.

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