The International Supply Chain Risk Management Network (ISCRiM)

The 10th International Research Seminar on Supply Chain Risk Management

September 6th - 7th, 2010

Organised by:
The School of Business and Economics
Loughborough University, UK

EPSRC
Engineering and Physical Sciences Research Council

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Proceedings of the

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CONTENTS

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FOREWORD

The International Supply chain Risk Network (ISCRiM) is a network of academics who are interested in conducting research in the area of supply chain risks. The ISCRiM network meets every year to exchange ideas and present the latest research regarding supply chain risks. This is the 10th year of its annual seminars and this book presents the proceedings of the seminar held at the School of Business and Economics at Loughborough University, UK. It is a collection of short papers presenting future research paradigms in the area of supply chain risks.

I would like to take this opportunity to thank the Engineering and Physical Sciences Research council (EPSRC) UK for supporting this seminar. I am also thankful to the School of Business and Economics, Loughborough University for helping me to host the seminar. The support of the ISCRiM members in submitting their papers for this book is gratefully acknowledged.

Samir Dani
Loughborough, September, 2010

Section 1

Supply Chain Risk Management theories

SUPPLY CHAIN RISK MANAGEMENT: WHERE ARE WE?

Professor Bob Ritchie and Professor Clare Brindley

University of Central Lancashire and Nottingham Trent University

ABSTRACT

The paper takes the form of a review of the presentations given at the first major international seminar on SCRM, held in Barcelona in 2009. By reviewing the contributions to the seminar, generic concerns, issues and potential solutions can be identified. Several key observations and outcomes are reported in the paper. Conclusions are made on current practitioner views of SCRM and the gaps that will provide fruitful foci for researchers in the field.

PURPOSE

The first major European and International Seminar on SCRM, addressed by speakers from 10 major international organisations and attracting 40 international delegates (mainly practitioners) took place in Barcelona in 2009. The primary purpose of this paper is to scan across the 10 individual presentations and the debate within the interactive sessions seeking to aggregate and evaluate successful practices within a broad framework of SCRM across both speakers and participants. The aim is not to replicate the individual presentations but rather to extract more generic concerns, issues and solution approaches. Establishing what has been found, what the current concerns and consequent activities are and what potential gaps remain is an appropriate means of developing the 'bigger picture' in relation to the field.

RESEARCH APPROACH:

The research adopts a qualitative methodology, the aim is not to quantify the number of points/observations but extrapolate the common issues and approaches being adopted by those in the field. Establishing a SCRM model or framework that would gain universal acceptance is neither practical nor possibly desirable at this stage of evolution in the field. With this caveat in mind a SCRM Framework (Ritchie and Brindley, 2009) was employed to provide some structure to the analysis and evaluation of the presentations and discussions in the seminar. This Framework divides the field into five major areas of activity, roles and responsibilities. It should be recognised that such frameworks inevitably lead to a degree of overlap between the five areas and consequently some degree of arbitrary allocation of specific activities.

Risk identification and modelling - incorporating the sources and characterisation of risks, what may trigger them and their relationship to the supply chain functioning effectively and efficiently.

Risk Analysis, Assessment and Impact Measurement **-** in terms of likelihood of occurrence and potential consequences.

Risk Management – generating and considering alternative scenarios and solutions, judging their respective merits, selecting solutions and undertaking the implementation.

Risk Monitoring and Evaluation – monitoring, controlling and managing solutions and assessing their impact on business performance outcomes. Effective governance structures and processes appear to be increasingly important in the SCRM arena, becoming a standard component

Organisational and Personal Learning *including* ***Knowledge Transfer*** – seeking to capture, extract, distill and disseminate lessons and experiences to others within the organisation and its associated supply chain members

FINDINGS AND ORIGINALITY:
All the speakers and most delegates attested to the enhanced profile of SCRM in their organisation and that the CEO and other Board Members were expressing greater interest in the Supply Chain. In some cases this was more selective, focusing attention on problematic elements with the potential to cause adverse press commentary, damaged reputation and criticism of the CEO.

Several conceptions of the supply chain structure were presented, each providing different insights to risk sources and their management. It is important to recognise that views on SC structure are not alternatives or mutually exclusive, rather they emphasise particular dimensions. The presentations by all of the speakers illustrate not only the diversity and range but the appropriateness and potential contribution in the specific contexts. The evidence could be distilled into 3 structures:

1. **End-to-End Chain**

The emphasis was towards involvement within and consideration of the entire supply chain (i.e. end-to-end), from raw material sourcing to consumption by the final consumer. The concerns with quality assurance of the baby products and the prevention of intrusions into the supply chain may well favour the use of a more simplified structure but still requires a comprehensive approach to its management. The associated requirement for 'visibility' of risk throughout the supply chain was identified by most participants

2. **Multi Layered Chain**

This demonstrated that conceptually and practically Supply Chains and their risk exposure may be divided into three layers or levels of decision making. The lowest level addressing the individual supply chain focuses on localised risks and their management. The second level encompasses the wider dimension than simply the single company-related supply chain, requiring consideration of risks impacting on the supply chains for all members of a specific sector or geographic location. The third level would have the capacity to dislocate supply chain activity across a wide range of supply chains with international consequences for most sectors and businesses. The current global financial crisis and the '9/11' terrorist attack are examples of this level of risk. Evidence from delegates at the seminar suggests that although the level 1 localised disruptions are the more frequent, the severity of the risk exposure and the consequences are more limited and businesses are generally well-equipped and experienced to manage these effectively, minimising the downtime and the costs.

3. **Multilevel network perspective**

This is another multi-level supply chain network perspective which yields the potential to focus on five key elements, incorporating the quality of the human resources, the processes in which they engage and the broader support and facilitation provided by the internal infrastructure and organizational structures and their engagement externally.
This more detailed perspective emphasises the networking or connectivity both within a particular level (e.g. employees' formal and informal links) and across the levels (e.g. interactions between the logistics element in the organisation and the production and administration processes).

Risk identification and modelling
Key elements in the initial identification of risks include:

- information sources, databases and corporate intelligence
- source of risk – categorisation by type, impact scale, function etc.
- the sequence or pathway of events that lead to the exposure
- what may trigger potentially latent risks
- characteristics of the risks and consequence severity as basis for classification
- comprehension of the key risk drivers and their potential impact

- potential impact on SC effectiveness and efficiency including wider business performance and survival.

Evidence from delegates suggests that this element is present and practised in most companies, although there was variation in the nature and degree of involvement. Risk taking in essence is the recognition that particular decisions or actions may lead to the realisation of positive performance outcomes, counter-balanced by the realisation that these may not be achieved fully or partially, even achieving outcomes below those achieved prior to the decision or actions. Information sources and corporate intelligence systems were seen as an integral part of the risk identification and modelling stage as well as subsequent stages. There was a general recognition that information systems could be developed to isolate and present risk data but currently there were few examples of this happening. The identification and evaluation of the factors driving the risk exposure in a given context was again a fairly well practised activity within SCRM. Several speakers and delegates identified the pressures within their organisations to improve the efficiency of the business, which roughly translated into focusing attention on driving down costs. The supply chain was being employed as the primary vehicle in achieving this objective. It was recognised that there is a fine balance between improving SC performance in financial terms and the increasing exposure to risks – dislocation of supply, reduced quality, insolvency of suppliers. The majority of presentations contained some reference to or exposition of some form of framework or model designed to provide support to the decision makers. The classification of risks associated with the Supply Chain are being tackled using different sets of criteria, recognising that such classifications must relate to the needs of the organisation at that particular point in time. Discussion on the approaches employed in assessing the likelihood of occurrence was somewhat limited and divulged few noteworthy contributions other than the more obvious emphasis on subjective approaches. The development of simulation models may often have built-in random number generators to facilitate the range and frequency of likely occurrence. A frequently used approach seeks to utilise the sources or causes and link these ultimately with the consequences that they may generate if triggered. It was evident that a wide variety of terms were employed within the participating organisations. However, these were all capable of being located within four categories: **Disruption** or **dislocation** of the SC in terms of supplying goods or services resulting in unscheduled downtime and failure to satisfy the customer's requirements on time; **Volatility** or **unpredictability** in terms of input and output prices which generates problems for planning and difficulties in advising customers of price changes in advance or having to absorb these within the businesses margins; **Inferior quality** of products and/or service, either upstream or downstream and **Reputation** which may be influenced by supply chain issues as well as those not directly related to the supply chain itself. These four categories of risk all have the potential to translate in to negative consequences for the firm's performance. Reduction in demand and revenues through failure to deliver, incurring penalty clauses, compensation claims, costs of reworking faulty products and the associated costs of rebuilding brand image will all have consequences for the financial performance.

The management of risk involving the generation and consideration of alternative scenarios and solutions, judging their respective merits, selecting appropriate solutions and undertaking the implementation was more implicit than explicit in the debate. Most presenters illustrated the risk management with specific examples and cases, which either demonstrated the value of risk management or otherwise. Risk monitoring and measurement and evaluation was viewed as central to effective management and effective Corporate Governance. Monitoring of every incident, the impact and the solutions implemented – seen as necessary to evaluate the effectiveness of the risk control and management effectiveness as well as providing the parameters to substantiate communication to the Board. Risk Appetite in terms of the acceptability of certain risks is seen as an evolving as the organisation matures and reflecting its positive and adverse experiences. In terms of Organisational and Personal Learning the tri-partite partnership of the corporation, the operator outlets and suppliers was built on the core values of openness, transparency, honesty and the aim of fair play and ethical behaviour. The

importance of building and sustaining relationships with other members of the SC was reflected by all the speakers.

RESEARCH IMPACT:

The key research agendas appear to be

- Simulation modelling to support decisions still in its infancy, although certain organisations have demonstrated the effectiveness of such tools.
- Governance issues were recognised as an important element in adopting SCRM, an issue attracting little attention in previous literature, indicating scope for further development
- Business Continuity emerged as a strong and common theme reflecting the need to avoid interruptions to the supply chain and redressing such incidents as effectively and efficiently as possible
- Evident association between SCRM and ERM with recognition that adoption of standards will enhance the position and development of SCRM.

PRACTICAL IMPACT:

- SCRM now features significantly at Board level
- Measures of SC performance are quite diverse – some appear idiosyncratic driven by the CEO's personal ambition to minimise 'bad news' and negative impact on share price and possibly preserving their own reputation, whilst others were driven by ensuring continuity of business operations.
- Most businesses highlighted 'cost reduction' as integral to the SCRM, also recognising that such strategies pose a danger of shifting the often fine balance within the SC causing an enhancement in risk exposure
- Alternative views of the composition, dimensions and levels within the Supply Chain illustrate the multi-functional dimensions of SCRM and the need to consider operational and strategic issues simultaneously
- Risk identification and categorisation used extensively with many novel approaches and differentiated terminology employed
- 'Visibility' throughout the entire supply chain seen as key requirement in most SCRM applications
- Strategic and operational objectives relating to supply chains including 'agile', 'lean', 'flexible', 'robust' and 'resilient' were evident across most of the supply chain cases presented
- Distinctive absence of specific Risk Management elements of SCRM, possibly because such activities are indistinguishable at times from other routinely performed management activities.
- Evidence of attention being given to disseminating SC information and the associated roles and responsibilities more widely within the organisation and externally with supply chain partners.

CONCLUSIONS:

SCRM has achieved position of significant importance in the Board room and parallels and interacts with other contemporary developments in many businesses, especially BCM and ERM. Risk Drivers have multiplied for every business with occurrence more prevalent and consequences more severe and utilising SCRM to achieve overall business efficiency is an approach adopted by many businesses. Pro-active is the by-word for SCRM although timely intervention may be more effective than too rapid a response. Case analysis from 10 businesses engaging with SCRM demonstrates that whilst the details of the application and development may differ, there remains a common strand of shared knowledge and understanding.

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WHAT IS SUPPLY CHAIN RISK MANAGEMENT IN THE PERCEPTION OF RESEARCHERS?

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ABSTRACT
Supply chain risk management (SCRM) is attracting researchers from different domains. They are therefore expected to have diversity in their perception of the scope of SCRM and of the appropriateness of different research tools. To characterize this diversity, we reviewed the researchers' output, i.e., the recent research literature and then we surveyed two focus groups (members of Supply Chain Thought Leaders and International Supply Chain Risk Management groups) with open-ended questions. Finally, we surveyed researchers during the 2009 INFORMS meeting in San Diego. Our findings characterize the diversity in terms of three "gaps": a definition gap in how researchers define SCRM, a process gap in terms of inadequate coverage of response to risk incidents, and a methodology gap in terms of inadequate use of empirical methods. One view that emerges is that SCRM is a superset of the overlap between supply chain management and enterprise risk management.

PURPOSE:
Researchers in supply chain risk management (SCRM) come from different more established areas. Hence, it is natural to expect a diverse set of viewpoints on what the scope of the field is and what research methodologies are appropriate at this stage. This diversity is unavoidable as we saw with supply chain management in the 1980s. It may even be beneficial in fuelling the kind of rapid growth in SCRM literature we have seen up to 2010.
However, this diversity affects collaboration with other researchers and the review process in journal publication. It can also hamper research engagement with industry. With a decade or so of SCRM literature behind us as of 2010, it is a good time to establish a consensus regarding SCRM research based on our understanding of industry need. A useful first step would be to characterize the diversity in scope and in the use of research methods among researchers. Considering the researchers' perceptions of industry needs – it is hard to escape the headline grabbing stories about major supply chain risk events – such characterization could help build a consensus with an eye towards industry need.

RESEARCH APPROACH:
We used field research approach for our study. First we obtained direct observations of SCRM research activities by reviewing some recent research literature. Our goal was to form our own perception regarding how researchers perceive the scope including the definition of SCRM. This step indicated diversity among researchers in their definition of SCRM, in their addressing different aspects of the process of SCRM and in their use of different research methodologies. Ultimately, this step helped shape our perception about three "gaps" in current SCRM research; (1) a definition gap, (2) a process gap, and (3) a methodology gap – that we discuss later. Next we surveyed two focus groups aided with a presentation and an open-ended questionnaire (Table 1). One group comprised supply chain management researchers at the 2008 Supply Chain Thought Leaders (SCTL) Conference in Madrid, Spain, and the other comprised SCRM scholars at the 2008 International Supply Chain Risk Management (ISCRiM) Conference in Trondheim, Norway. We obtained 42 responses to the open-ended questionnaire from the attendees at these two mini-conferences. Their responses helped us to further characterize the diversity of scope in terms of the definition of supply chain risk and of SCRM and also led to a starting point for scoping SCRM. Finally, we used a presentation and a questionnaire with closed-ended as well as open-ended questions to survey a broad-based group of operations management researchers who attended our keynote speech on SCRM during the 2009 Institute of Operations Research and Management Science (INFORMS) National Meeting in

San Diego. We distributed the questionnaire to approximately 200 attendees who attended the keynote speech on SCRM during the 2009 INFORMS San Diego meeting and obtained 133 responses albeit some with incomplete responses to the open-ended questions. For more details, see Sodhi, Son and Tang (2010).

FINDINGS AND ORIGINALITY:

Three "gaps" were apparent in the sample of articles we surveyed as a first step in forming our opinions. One is a *definition gap*: there appears to be an absence of any consensus on a definition or scope for supply chain risk, and consequently for SCRM. The second is a *process gap*: only a small percentage of articles in our sample covered the response element of SCRM for catastrophic risks with a few more looking at response to "operational" risks with high frequency and low per-event impact. Finally, we observed a *methodology gap*: most articles in our sample were either conceptual or framework-type papers and it appears that empirical work is not extensive in the area of SCRM.

Next, our findings from surveying the focus groups at the SCTL and the ISCRiM mini-conferences underscored our perception regarding the definition gap. We summarized the responses of the surveyed participants to the open-ended questions (Table 1) into different categories.

No.	Questions
Q1	What is supply chain risk management (SCRM)?
Q2	How is SCRM different from supply chain management?
Q3	What is the link between SCRM and Enterprise Risk Management (ERM)?

Table 1: Questionnaire for the first survey (SCTL and ISCRiM)

The first question was about the respondent's definition of SCRM. The tabulated results show that one-third of the respondents take a probabilistic approach and define SCRM as dealing with probabilities related to supply-demand matching (Table 2). About the same number take an operations view in suggesting that SCRM deals exclusively the risks stemming from supply chain operations. About 7% of the respondents believe that SCRM deals with risks arising from not only the operational aspects, but also the strategic aspects of supply chain. One interesting observation is that although a fifth of the respondents believe SCRM deals with rare but high impact events such as plant fires and natural disasters - this proportion could rise to nearly half if we include "dealing with the unknown" and "dealing with disruptions/disasters" as independent responses -- research articles tend to focus on dealing with supply delays or other frequent disruptions that have low-to-moderate impacts. It could be that researchers cover supply chain risks that are more easily quantified with higher data availability but it could also be more fundamentally linked to researchers' understanding of SCRM dealing with risks within supply chain management.

Q1: What is supply chain risk management (SCRM)?	
Dealing with supply-demand stochastic (probability)	33.3%
Dealing with risk within supply chain operations	31.0%
Focus on low probability-high impact events	19.0%
Dealing with the unknown	14.3%
Dealing with disruptions/disasters	11.9%
Dealing with risk within supply chain strategy	7.1%
Dealing with stochastic, but need new probability-based approaches	4.8%
Dealing with financial risk	4.8%

Table 2: Response to Q1 - What is supply chain risk management? (N=42; some responses fell into more than one category.)

The second question (Q2) in our open-ended survey was to find out the link between SCRM and supply chain management. Indeed, as already speculated, about half (52.4%)

participants view SCRM as a subset of supply chain management, an already established area of research and business practice. More than half of these (28.6% of the total) believe that SCRM is part of supply chain management, but with additional focus on risk elements. On the other hand, half the respondents believe SCRM as having elements outside supply chain management with 16.7% of the respondents regarding SCRM as being entirely outside of supply chain management (Table 3).

Q2: How is SCRM different from supply chain management?	
SCRM is a subset of SCM	52.4%
SCRM is a subset of SCM, with additional focus on risk elements	28.6%
SCRM has something outside SCM	16.7%
SCRM is a subset on SCM but additional focus on supply sources	2.4%
SCRM overlaps with SCM and risk management, finance	2.4%

Table 3: Response to Q2 - How is SCRM different from supply chain management (SCM)? (*N*= 42 respondents. Some responses fell into more than one category.)

With the third question (Q3) about "the link between SCRM and enterprise risk management", we intended to find out how SCRM differs from enterprise risk management (ERM). Nearly three-fourths (74.2%) of the respondents believe SCRM to be a subset of ERM or an extension of it (Table 4). Also, 13.0% of these respondents underlined that the boundary of the traditional ERM tend to limit to the focal firm and the immediate surroundings but the boundary of SCRM is more extensive. Importantly, nearly a fifth the respondents believe that SCRM is separate from ERM (19.4%) while a tenth of the respondents place SCRM at the intersection of supply chain management and ERM (9.7%).

Q3: What is the link between SCRM and Enterprise Risk Management (ERM)?	
SCRM is a subset of ERM	41.9%
SCRM is an extension of ERM	32.3%
SCRM is separate from ERM	19.4%
SCRM is the overlap between SCM and ERM	9.7%

Table 4: Response to Q3 - What is the link between SCRM and ERM? (Percentage was calculated out 31 respondents. Some responses fell into more than one category.)

An interesting picture emerges that could become the basis for defining SCRM while satisfying most of the respondents of the last two questions in our focus groups (Q2 and Q3). This view is that SCRM has two parents: supply chain management and enterprise management. It has traits from both parents but is not a strict subset of either. Moreover, it is more than the overlap between its two parents (Figure 1). However, this view has not yet been validated with researchers and is offered here for further research and discussion.

Finally, at the 2009 INFORMS San Diego meeting, we posed three sets of questions about the definition gap, process gap, and the methodology gap respectively. More than 80% of 124 respondents agreed (score of 5 or more on a 7-point Likert scale) that "there is no clear consensus on the definition of supply chain management". Responding to the question about the terms in which SCRM should be primarily defined, nearly half (47%) of the 133 respondents agreed that SCRM is about dealing with low-probability and high-impact events. On the other hand, a tenth (10%) of the respondents chose to point out the risks stemming from supply-demand stochastics. There were those who preferred to think in terms of supply chain strategy (10%) and those who emphasized supply chain operations (20%) instead. Of the remaining 13% who selected "other", more than half (7.5% of all the respondents) suggested that SCRM to encompass all of these risks. Regarding the process gap, nearly 70% of the 125 respondents confirmed that there is a lack of the research on response relative to prevention and mitigation. Finally, we sought to verify the perception of the methodology gap. A majority of the respondents agreed

with this statement with nearly 80% of the 125 respondents giving a score of 5 or higher as their response (see Sodhi, Son and Tang, 2010 for details).

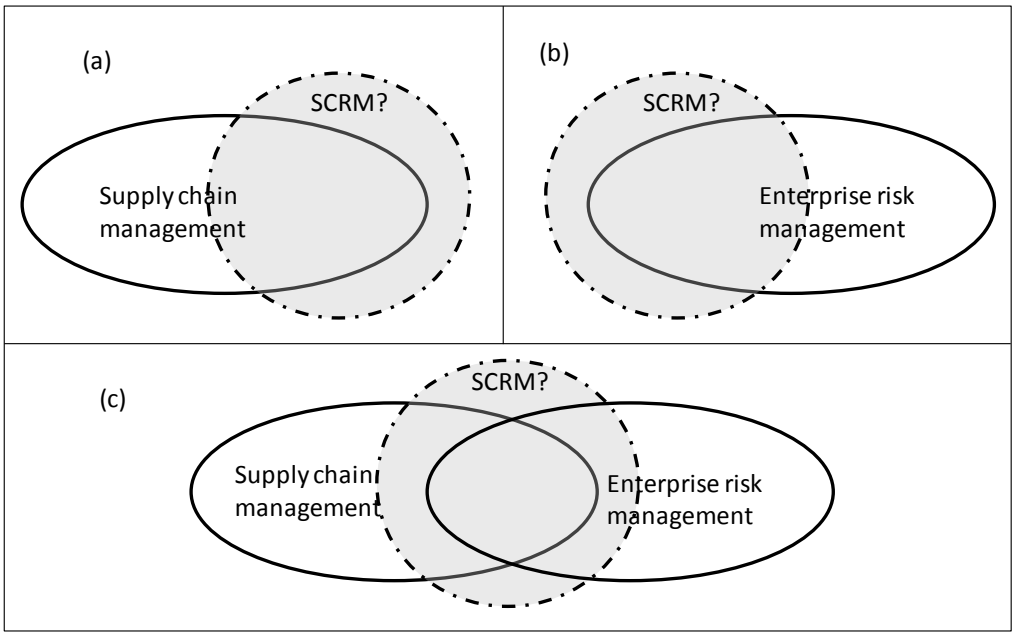

Figure 1: A possible scope for SCRM combining diverse views of respondents (a) a part of supply chain management but extending it (b) as a part of enterprise risk management but extending it and (c) as a part of both but extending the overlap.

CONCLUSIONS:

We found there are three "gaps" pertinent to future research in SCRM: (1) no clear consensus on the definition of SCRM; (2) lack of commensurate research on response to supply chain risk incidents; and (3) a shortage of empirical research in the area of SCRM. The INFORMS respondents provided initial answers on how to go about closing these gaps. Taken together, their suggestions point to the need for more involvement with industry for case-study and event-study based research, while at the same time pointing out the need for more conceptual work on which to base this empirical research. Their suggestions are also aimed towards journal editors and reviewers in being more open-minded to research methodology for SCRM. From the two focus groups, SCTL and ISCRiM respectively, it appears we should consider the area of overlap between supply chain management and enterprise risk management as a start.

Future work should include a similar study of practitioner communities to determine the particular risks in their respective companies, the type of data they can provide regarding risk events and what type of collaborations they want to have with academic researchers. The present study combined with such a practitioner study would help create a research agenda for SCRM researchers and journal reviewers. Given that many academic researchers also teach, we could additionally expand our study to establish a teaching agenda for SCRM, possibly from an employer as well as researcher viewpoint. Taking a larger picture, there are other emerging areas in operations management such as sustainability that could benefit from a study of scope and methodology diversity within the researcher community along the lines of our study.

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WHEN DO SUPPLY CHAIN DISRUPTIONS BECOME THE NORM? INSIGHTS FROM NORMAL ACCIDENT AND HIGH RELIABILITY THEORIES

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ABSTRACT
When do supply chain disruptions become the norm? This an important question, given that firms around the world are increasingly exposed to the risk of disruptions that impede their supply chain relationships and associated operations. This study draws on normal accident theory and high reliability theory to devise and test a model that predicts the frequency of supply chain disruptions.

PURPOSE
To answer the research question stated in the title and to understand the relationship between supply chain characteristics and the frequency of supply chain disruptions, we draw on organizational theories that explain how accidents in socio-technical systems unfold and which system characteristics increase the likelihood of their occurrence. Specifically, we apply insights from normal accident theory and high reliability theory. The central idea behind the proposed conceptual framework is that the frequency of supply chain disruptions is a function of certain supply chain characteristics.

Normal accident theory
Based on an in-depth analysis of a near-disaster at a US nuclear power plant, Charles Perrow proposed normal accident theory (NAT) that attempts to explain why complex socio-technical systems fail (Perrow, 1984). This theory links the occurrence of system accidents (i.e., accidents that arise from the interaction among the system components rather than from the failure of an individual component) to the structure and technology of a system. Perrow's theory holds that two system characteristics are relevant for the probability of occurrence and the severity of system accidents: (1) interactive complexity of the system and (2) tight coupling of the elements in the system.

First, a socio-technical system such as a supply chain is complex, if it is characterized by a large number of (varied) elements that interact in a non-simple way (Simon, 1962). Obviously, with increasing levels of complexity, a system becomes more challenging to manage and control. However, according to NAT, complexity is an essential, but not sufficient characteristic of high-risk socio-technical systems. Instead, it is argued that complexity becomes particularly dangerous, if the interactions among the system's components are nonlinear (interactively complex system). In Perrow's language, linear interactions lead to predictable and comprehensible event sequences, while nonlinear interactions lead to unexpected event sequences. He argued that interactively complex systems were "intellectually unmanageable," because the interactions among its components may result in unforeseen system behaviour. Small, independent failures can interact in unplanned ways and produce unfamiliar, unexpected events that are not immediately comprehensible. In particular, the system's reaction to corrective actions is hard to predict, since positive or negative feedback loops may propagate, attenuate, or even reverse the intended effect in an unforeseeable manner.

Second, a system is tightly coupled, if the components are interrelated in such a manner that there are few possible substitutions, time-dependent processes, and minimal slack or buffers (Galbraith, 1973; Perrow, 1984). Often, tight couplings are accepted as the price for increased efficiency and high performance standards. For example, close collaboration between buyers and suppliers is usually advocated in current marketing and supply chain management paradigms. However, in tightly coupled supply chains, the margin of error is reduced. Similar to the domino effect, a change in one tier may trigger a rapid and strong change in related tiers. This implies that disturbances may propagate rapidly and spread

almost unobstructed throughout the system. In contrast, loosely coupled systems are able to absorb failures, environmental changes, or unexpected system behaviour. In summary, both high levels of interactive complexity as well as high levels of tight coupling make a system vulnerable to accidents. Given that a system combines both, it is virtually impossible to predict and protect against all the ways in which the system can fail. In such systems, accidents are inevitable, i.e., normal.

NAT offers an insightful underpinning for the investigation of supply chain disruptions. It suggests that supply chains that are characterized by a high degree of interactive complexity and a high degree of tight coupling will suffer from a higher frequency of supply chain disruptions. However, NAT's core concepts of interactive complexity and tight coupling are hard to grasp in general, and in the supply chain context in particular. For example, the operationalization of the concept of tight coupling has proven to be difficult in the context of organizations (Wolf, 2001). For this reason, critics (e.g., Hopkins, 1999) have contended that NAT is difficult to subject to empirical tests. Therefore, we will focus on complexity only. Several studies have worked on conceptualizing supply chain complexity. So far, however, there is no consensus on the precise definition of supply chain complexity. Vachon and Klassen (2002) outlined two dimensions that contribute to supply chain complexity: (1) information processing and (2) technology. Choi and Krause (2006) conjectured that (supply base) complexity is driven by (1) the number of suppliers, (2) the differentiation among the suppliers, and (3) the inter-relationships among the suppliers in the supply base. In the organizational design literature, the concept of (structural) complexity has been split into three dimensions: vertical complexity, horizontal complexity, and spatial complexity (e.g., Daft, 2006). The latter conceptualization can be easily transferred to the supply chain context. *Horizontal complexity* refers to the number of direct suppliers. *Vertical complexity* refers to the number of tiers in the upstream supply chain. *Spatial complexity* refers to the geographical spread of the supply base (Choi, Dooley, & Rungtusanatham, 2001; Choi & Hong, 2002; Vachon & Klassen, 2002). Accordingly, it can be argued that horizontal, vertical, and spatial complexity exacerbate supply chain complexity and, thus, are associated with increased uncertainty as well as poorer transparency and visibility, leading to higher exposure to supply chain disruptions (Choi & Krause, 2006). Thus,

Hypothesis 1a: *Horizontal supply chain complexity has a positive effect on the frequency of supply chain disruptions.*

Hypothesis 1b: *Vertical supply chain complexity has a positive effect on the frequency of supply chain disruptions.*

Hypothesis 1c: *Spatial supply chain complexity has a positive effect on the frequency of supply chain disruptions.*

High reliability theory

Charles Perrow (1984) made an important contribution in identifying interactive complexity and tight coupling as major risk-increasing system characteristics. His conclusion, however, that accidents are inevitable in such systems has been criticized as overly pessimistic (Rijpma, 2003). In particular, high reliability theory has questioned the main implication of Perrow's NAT, arguing that organizational and structural precautions can reduce the likelihood of normal accidents (e.g., Roberts, 1990). High reliability theory examined organizations that show great proficiency in dealing with unexpected events and delineated their characteristics. Firms which possess characteristics of high reliable organizations can be successful even in the presence of interactive complexity and/or tight coupling in their supply chains. However, an issue in the empirical test of high reliability theory literature is that it is not always precise and sometimes even inconsistent. For example, it was suggested that organizations can buffer the impact of critical situations and make fewer mistakes through redundancy (Roberts, 1990). In contrast, it was also argued that redundancy may backfire in crisis situations (Sagan, 2004). Another suggestion was that the impact of critical situations could be reduced simply by giving personnel the right training. However, other studies contended that training can reduce flexibility, which could impair the organization's ability to respond during critical situations (Price, 1977). Therefore, we focus on a specific characteristic that has been repeatedly

argued to be reliability-enhancing: decentralized decision making (Roberts, Stout, & Halpern, 1994). If the purchasing and/or supply chain function is decentralized, most information about supply chain issues is generated and located closer to the supplier. Decentralized purchasing provides more responsiveness to warning signals and looming disruptions. Therefore,

Hypothesis 2a: *Decentralization of the purchasing department moderates the positive relationship between horizontal supply chain complexity and the frequency of supply chain disruptions.*

Hypothesis 2b: *Decentralization of the purchasing department moderates the positive relationship between vertical supply chain complexity and the frequency of supply chain disruptions.*

Hypothesis 2c: *Decentralization of the purchasing department moderates the positive relationship between spatial supply chain complexity and the frequency of supply chain disruptions.*

RESEARCH APPROACH

Data

To test the hypotheses on a broad empirical basis, we conducted a large-scale survey of firms in Germany, Austria, and Switzerland. Primary data were collected by means of a self-administered Internet-based survey. Contact addresses were obtained from a commercial business data provider, with each respondent selected on the basis of job function, firm size (number of employees > 50), and industry sector (SIC code). The survey targeted senior managers in purchasing or supply chain management departments who were likely to have an overarching, boundary-spanning view of their firms' supply networks and supplier activities. Our methodology incorporated several procedural remedies for controlling common method variance (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Accordingly, the survey instrument provided only general information about the study's objectives, but no clues about the actual relationships under investigation. We offered anonymity (on the level of the respondent) and confidentiality to reduce the chances of responses that were socially desirable or consistent with how respondents believe researchers want them to respond. Due to missing values, several cases were not useable for this study. After three follow-up e-mails and reminder phone calls, we received 398 useable responses. The data collection yielded a heterogeneous sample covering a broad range of manufacturing industry sectors and firm sizes and revealed no indication of systematic bias.

Measures

The questionnaire asked the respondents to indicate (1) how many supply chain disruption they experienced in their major product line during the last twelve month prior to data collection (*number of supply chain disruptions*), (2) how their supply chains were structured (supply chain complexity), and (3) how their purchasing and supply chain function was structured internally. *Horizontal supply chain complexity* was measured with a single item asking for the number of direct suppliers. Likewise, *vertical supply chain complexity* was measured with a single item asking for the number of tiers in the upstream supply chain. To measure spatial supply chain complexity, we calculated the Herfindahl index, a common concentration measure, of purchasing volume broken down by continents. *Decentralization/centralization* of the purchasing department was measured with a single item asking the respondents to assess the organizational structure on a five-point bipolar rating scale anchored at "strongly decentralized" and "strongly centralized." We controlled for firm age, firm size, and competitive intensity. The latter was measured on a four-item scale developed and validated by Jaworski and Kohli (1993).

Estimation strategy

Given that the dependent variable (number of supply chain disruptions) was nonnegative event counts that exhibited overdispersion (i.e., the variance in number of disruptions was greater than its mean), we opted to use the negative binomial model to test our hypotheses – rather than a standard Poisson model. Accordingly, for each firm *i*, the

expected number of supply chain disruptions y_i can be expressed as $E(y_i \mid x_i) = e^{\beta x_i' + \varepsilon_i}$ where x_i are our independent variables of interest and ε_i the random error. Several models were estimated in a hierarchical approach using maximum likelihood estimation.

FINDINGS AND ORIGINALITY

The results of the regression analyses indicate that supply chain complexity, in fact, increases the frequency of supply chain disruptions. For example, as shown in Figure 1, the frequency of supply chain disruptions increases with increasing number of suppliers (horizontal supply chain complexity). In addition, we received empirical support for the hypothesized interaction effects. As shown in Figure 1, centralized purchasing departments are the best choice, if the number of direct suppliers is low. However, in case of a large amount of direct suppliers, centralized decision making is incapable of dealing with the complexity involved. Here, decentralized organizational structures lead to a better management of complexity and, thus, to a lower frequency of supply chain disruptions.

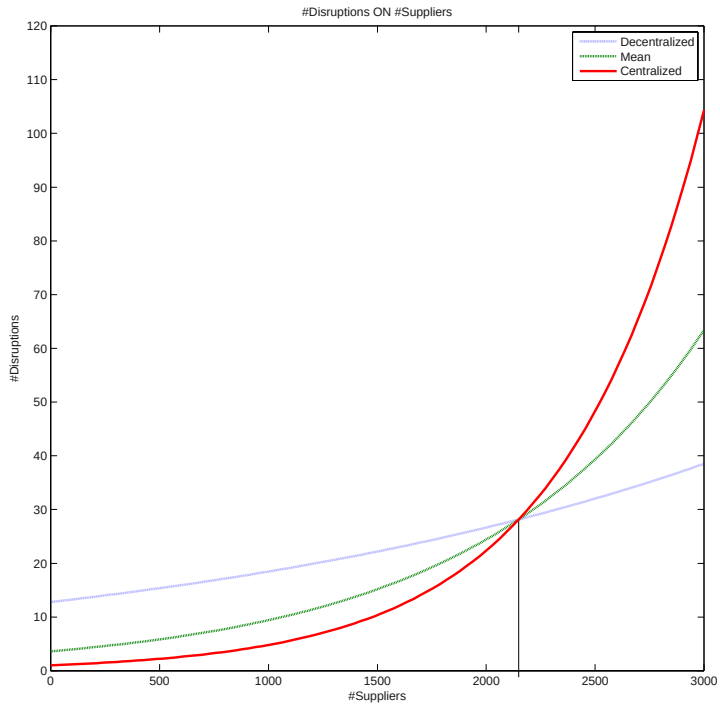

Figure 1: The interaction effect of decentralized decision making and horizontal supply chain complexity

RESEARCH IMPACT

Our study provides the first empirical examination of NAT and high reliability theory in the supply chain context. More specifically, we test the hypothesis that supply chain complexity affects the frequency of supply chain disruptions, which has been proposed in several prior studies (Choi & Krause, 2006; Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007).

PRACTICAL IMPACT

The insights from NAT can assist practitioners in assessing the impact of supply chain management strategies, like outsourcing or supply base reduction, in the light of interactive complexity. The message for managers is: reduce the complexity in your supply chains! If the reduction of complexity is not possible, high reliability theory identifies ways to circumvent the complexity trap.

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SUPPLY CHAIN RISK & RETURNS MANAGEMENT (SCR^{2}M)

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Purpose of this paper

Several business trends like outsourcing, globalization, shorter lead times and reliance on supply networks for competitive advantage contribute to create an increasingly risky environment (Zsidisin, 2003). Risk exists at various levels, inside the company and along the external processes (Borghesi and Gaudenzi, 2006). The aim of risk management is the protection of the business from adverse events and their effects. Risk was defined as a chance of danger, damage, loss, injury, or any other undesired consequences (Harland et alii, 2003). Both in the intra-organization perspective and particularly at a network level, risk management aims to protect the capability to achieve the main objectives, and for this reason the commitment amongst supply chain members in managing risks is essential (Jüttner et alii, 2003). Therefore, risk management is becoming a value-added, transversal process which protects the capability of the companies to achieve their objectives (Young and Tippins, 2002).

Assessing risks properly and managing simultaneously cause-and-effect relationships among different risks seem essential to improve the capability of companies to control the sources of vulnerability and hence to support the competitiveness. Otherwise, there is a need to increase constantly the organizational competencies and the managerial approaches which may support an effective risk management. The integration between risk management and other processes is well documented in the literature. For example, corporate governance, financial management, business continuity management, safety and security, process controls, demand management are often integrated within the risk management practices.

In our contribution we explore how risk management can support the effective and efficient movement of products backwards in a supply chain. There are many types of returns for different reasons: consumers' returns, marketing returns, asset returns, product recalls and environmental returns (Rogers et alii, 2002). As we mentioned returns management is a process focused on the reverse supply chain, and effective management can be complicated by the boundary spanning nature of this process within a firm and across the entire supply chain (Rogers et alii, 2002). Recently, the literature across several related disciplines such as logistics, marketing, operations management and particularly supply chain management, suggests that the returns process is, in fact, cross-functional in nature (Petersen and Kumar, 2009). Recall products, product return behaviour, reverse logistics, product recovery, remanufacturing, recycling and closed-loop supply chain issues are being increasingly addressed by various empirical studies (Thierry et alii, 1995; Stock, 1992; Dowlatshahi, 2000; De Brito and Dekker, 2004; Rogers et alii, 2002). Because returns management is a multi-functional activity not belonging to the domain of any single functional area of the firm, it similarly lends credence to the logic of multi-disciplinary investigation.

Thus the paper explores how and where returns management process may represent a set of competencies, managerial approaches, techniques and know-how which can support the effective management of risks along supply chain processes. At the first step the paper provides a literature review related to these broad but crossing disciplines: risk management and returns management. Risks and returns are events which seem to be distant but in fact are related from different perspectives. Recalls, for example, are described and managed both in the risk management tradition and also in returns management. Recalls which "are a form of return that are usually initiated because of a

safety or quality issue. They require more upfront planning then most other returns types, and this planning is central to managing them effectively" (Smith et al, 1997). Returns are events which can be investigated in the perspective of product design, supply chain management, marketing and value for customers, but in fact can be also analysed as consequence of any mismanagement somewhere along the supply chain.

At the second step the paper investigates the managerial link between returns and risk, both analysing the categories of risk and the different perspectives related to an holistic risk management. Authors have broadly described risks within different categories: for example, strategic risk, operative risk, financial risk and hazard; demand risk, supply risk, network risk and environmental risk (Christopher et alii, 2003); supply risk, operational risk, demand risk and security risk (Manuj et alii, 2008). Managing risk supports the prevention and protection from critical threats within different processes (like purchasing, manufacturing, demand et alii) and domains (like safety, security, vulnerability, environment, project management et alii). Managing returns supports the reduction of unnecessary costs (processing time, transportation, handling, inventory control, asset recovery) and the protection of customer value (product quality and performance, problem solving, brand reputation). With regard to this aspect, the first *research question* of the paper is:

> RQ1: are returns potential risks which may affect the supply chain competitiveness? In this sense, are returns management strategies potentially supportive for an effective risk management?

Risk treatment is traditionally defined as the activity of selecting and implementing appropriate control measures to modify the risk. Risk treatment includes as its major element, risk control (or mitigation), but extends further to, for example, risk avoidance, risk transfer and risk financing. All the companies strategies impact onto the risk landscape, increasing or reducing the exposition to risks both of the single company and also of the entire supply chain. Unfortunately, not all the decisions and strategies are evaluated in terms of risk. Agility versus leaness, postponement versus speculation, outsourcing versus vertical integration, single sourcing versus supplier diversification, are different strategies which should be properly analysed and selected depending on the potential opportunities and also threats which could be generated. Returns avoidance is a relevant part of returns management process and it refers to the activities to prevent and eliminate the causes of returns (defective product and packaging design, conforme to legislative mandates, poor demand management). Among the returns strategies, returns avoidance is increasingly becoming a 'decision driver' and a strategy in many businesses; poor quality products will create excessive return situations for retailers and customers, creating operational and profitability concerns for them. Then gatekeeping represents all activities that limit returns to enter in the reverse flow. Gatekeeping involves the screening and authorization of products entering the return flow. Effective gatekeeping ensures that only appropriate products are returned, thus avoiding unnecessary expenditures on products from which no further value can be extracted. Gatekeeping is often identifiable as an indicator of collaboration within the supply chain between the manufacturer and the retailer. There is therefore a need to manage returns across multiple functional areas and even firms within the supply chain, also in terms of potential impact in reducing the global risk exposure. With regard to this aspect, the second *research question* of the paper is:

> RQ2: are returns management strategies– like returns avoidance and gate keeping— helpful for implementing risk mitigation strategies?

At the third step the paper analyses how returns management practices may support the risk management process at the different phases of procurement, production and distribution. In this section the risk management approaches (risk prevention, reduction and transfer) are described and the returns management practices will be incardinated within these framework. With regard to this aspect, the third *research question* of the paper is:

RQ3: how and where – in terms of functions, processes and areas— can we concrete overlap risk management actions and returns polices? How to define the potential managerial benefits of this integration?

DESIGN / METHODOLOGY / APPROACH

This paper is based on a in depth literature review and a qualitative study. The research is also supported by different research cases from a wide range of sectors. The relationships between risk management and returns management is not well explored in the literature, thus a qualitative research methodology was chosen. Such approach is appropriate when the phenomenon under observation is unexplored or where the research is limited. For these reasons we considered the grounded theory approach the most suitable research method in order to understand in depth the nature of the phenomenon (Zsidisin, 2004; Flint et alii, 2002; Strauss and Corbin, 1998; Ellram, 1996). Data are collected in several firms in different industry sectors along different dimensions such as function (logistics, production, finance, security, operations, marketing, sales) at senior level managers. The sample of the companies was pre-selected in order to get firms really involved in the academic research based on the good relationship between University and the firms in the last years. We focused the research on individual managers perceptions of relationship between risk management and managing returns. Interviews got individually with each participating senior manager, and each interview will last 90-120 minutes. The depth interviews were open ended and discovery oriented, started with a grand tour technique borrowed from ethnography (McCracken, 1988). These topics were indentified from previuos studies and research in risk management and returns management (Christopher, 2004; Manuj and Mentzer, 2008; Rogers et al, 2002).

FINDINGS

The paper provides a framework for the applicability of returns management practices within risk management decisions.

RESEARCH IMPLICATIONS

The framework is conceptual developed. It should be tested in companies and supply chains in order to be generalizable using a ground theory approach. This research aims to enlarge the boundaries of risk management applicability in supply chains.

PRACTICAL IMPLICATIONS

This research supports managers in implementing strategies and choosing risk management actions taking in account the correlations between risks and returns.

CONCLUSION

The paper describes how some returns management strategies, as returns avoidance and gatekeeping, should support an effective risk management, particularly risk mitigation strategies, across supply chain.

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THE INFLUENCE OF COGNITIVE BIASES ON MANAGERIAL PERCEPTIONS OF SUPPLY CHAIN RISK

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ABSTRACT

Previous research on Supply Chain Risk has mainly looked at Supply Chain risks from a structural perspective, whereas the behavioural perspective is currently still under-researched. However, practice and research are constantly delivering evidence that human factors such as experience, preferences, risk attitudes and biases play a crucial role in the perception of risk and in decision making. In particular, cognitive biases shape risk perception at individual level and can lead to suboptimal decision making, which in the case of Supply Chain Risk Management (SCRM) can mean neglecting or underestimating Supply Chain risks and not investing enough in their prevention and mitigation. This short conceptual paper suggests a set of four specific cognitive biases known from previous research to lead to overconfidence and lowered risk perception to account for variations in risk perception in supply managers, thus influencing investment decisions associated with measures of SCRM.

PURPOSE:

The purpose of this study is to investigate how heuristics and cognitive biases in individual Supply Chain managers shape their perceptions of Supply Chain Risk, and how this impacts SCRM. To this purpose the study imports established theories from behavioural decision research, which is a distinct area of psychology that employs normative models to explain the faulty decision processes of individuals (Bazerman & Tenbrunsel, 1998).

RESEARCH APPROACH

As the focus of this study are behavioural factors in SCRM, the study is looking at Supply Chain Risk through a theoretical lens from behavioural decision research – that of Behavioural Decision Theory. This relationship is presented graphically in the figure below:

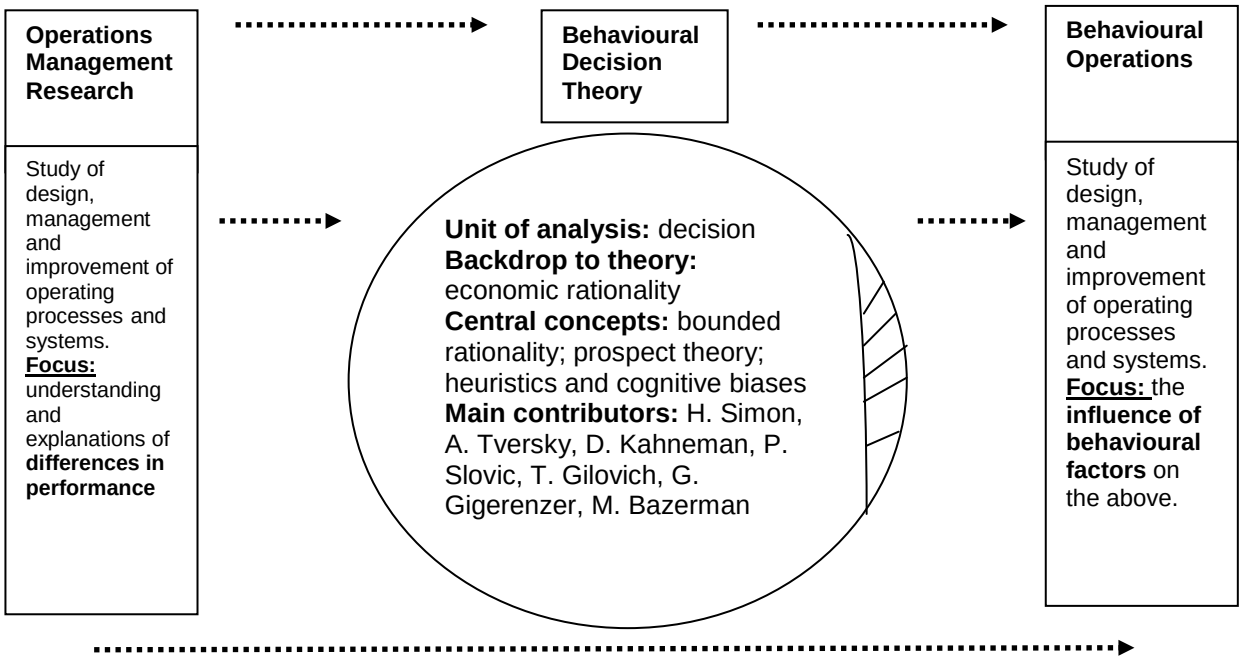

Figure 1: Behavioural Decision Theory as the theoretical lens for the study

Figure 1 provides an illustration of the role of Behavioural Decision Theory (BDT) for this study. In order to incorporate behavioural research into decision making in Operations Management (OM) research, the robust framework of Behavioural Decision Theory is used as a lens to look through at decision making in management of operations. BDT is an appropriate lens for this study as it works with concepts of bounded rationality and human cognition, and specifies the decision as its unit of analysis. By studying OM through the framework of BDT a research is conducted which is absolutely in line with the current definition of Behavioural Operations.

There is currently a research gap in SCRM related to the neglect of behavioural factors in OM research in general. Previous studies have looked into Supply Chain Risk from a structural perspective, but the behavioural perspective so far remains under-researched. However, people are crucial to the OM phenomena and must not be ignored if the problems are to be adequately analysed and solutions to be optimised (Bendoly et al., 2006; Gino & Pisano, 2008).

This study is looking at Supply Chain Risk from a behavioural perspective, and in order to do this it imports concepts and findings from behavioural decision research into SCRM. In order to investigate whether overconfidence biases lead managers to unwittingly increase levels of Supply Chain Risk, and whether cognitive biases influence managerial decisions in SCRM, the following research questions are formulated for this research:

RQ1. Do cognitive biases account for variations in risk perception of supply managers?

RQ2. Are investments in measures of Supply Chain Risk prevention and mitigation associated with individually perceived levels of Supply Chain Risk?

In order to answer these questions, the model depicted below is currently being tested:

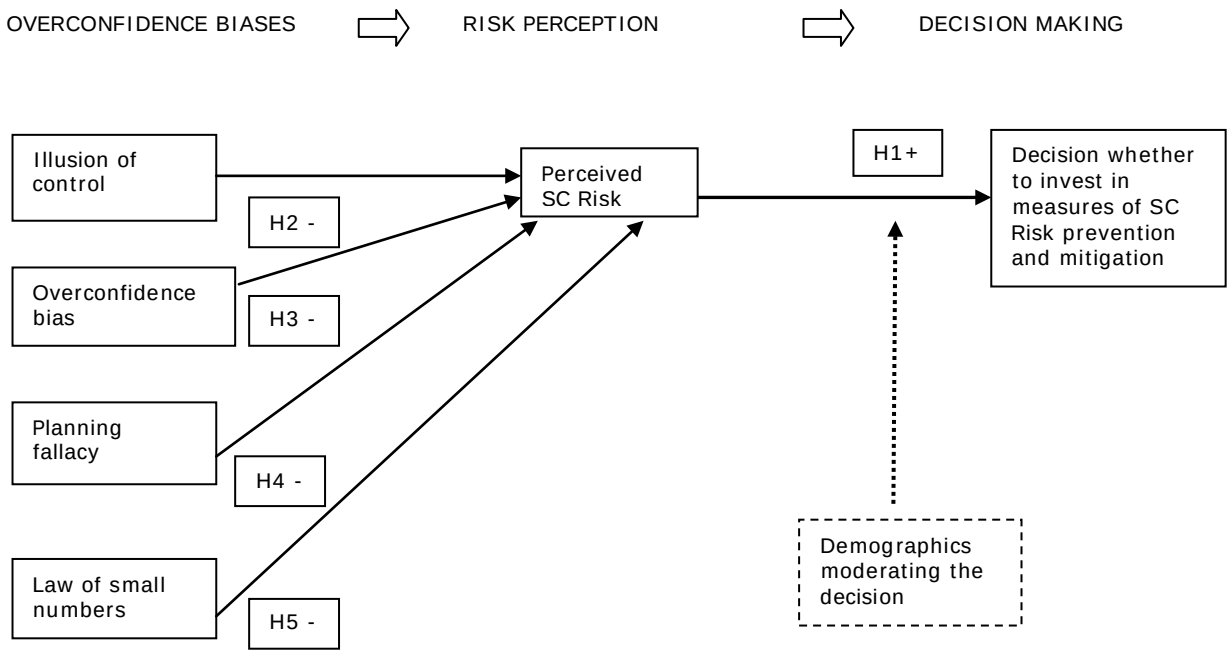

Figure 2: Behavioural decision making model of SCRM investment

Building on previous research that has established that risk perception influences decision making of individual managers (Siktin & Pablo, 1992; Weber & Milliman, 1997; Maytorena

et al, 2007; Winch & Maytorena, 2009), the conceptual model hypothesises that managers will only decide to invest in measures of SC Risk prevention and mitigation if they perceive sufficient levels of risk, and that they will decide not to invest in those measures when they perceive the levels of Supply Chain Risk to be lower than they objectively are:

H1: There is a positive relationship between the individual perception of SC Risk and the decision whether to invest in measures of SC Risk prevention and mitigation.

Previous studies in business research have found that risk perceptions differ because certain types of cognitive biases lead individuals to perceive lower levels of risk (Houghton et al., 2000; Simon et al., 2000; Sherman et al., 2006; Zane et al., 2007). These biases are: illusion of control, the overconfidence bias, the planning fallacy and the belief in the law of small numbers.

Illusion of control is a cognitive fallacy which occurs when a person overestimates the extent to which his/her skills can increase performance in situations in which chance actually plays a larger role than the skills of the individual (Langer, 1975). Although practice and research show that the levels of Supply Chain Risk have significantly increased in the past few years, measures of Supply Chain Risk prevention and mitigation are still not the major concern of managers when it comes to making investments. The conceptual model suggests that this is in part due to the illusion of control bias, which makes managers believe that their skills and knowledge will help them prevent possible disruptions, although individual managers do not have control over the whole Supply Chain:

H2: Illusion of control reduces the perceived Supply Chain Risk.

Overconfidence bias relates to overestimating the probability of being correct, and to a failure to recognise the limits of one's own knowledge and judgment capabilities (Simon et al., 2000). As overconfidence results in a premature cessation of problem-solving efforts, and leads individuals not to adequately revise their estimates upon receiving updated information (Zane et al., 2007), it is suggested that overconfidence in Supply Chain managers prevents them from revising their estimates regarding the levels of risk in the Supply Chain although there is now sufficient evidence from practice and research that the levels of Supply Chain Risk have increased globally:

H3: Overconfidence bias reduces the perceived Supply Chain Risk.

Planning fallacy is a cognitive bias which leads individuals to be overly optimistic when estimating the future development of situations. In particular, the planning fallacy makes people consider mainly positive out of all possible events, and ignore many negative events which are however also realistic (Buehler et al., 2002). In this study it is hypothesised that Supply Chain managers are influenced by such a bias when planning future activities, considering mainly positive developments and neglecting things that can go wrong, which leads them to perceive levels of risk much lower than they objectively are:

H4: The planning fallacy bias reduces the perceived Supply Chain Risk.

Law of small numbers is a fallacy which leads the decision maker to make judgments about an entire population based on a very small sample (Tversky & Kahneman, 1971; 1974). Supply managers may be encouraged by limited feedback from other nodes in the Supply Chain, and form their perception of SC risk based on limited sources of information that have not accounted for potential risks, or previous risky circumstances which however did not end in a disruption:

H5: Belief in the law of small numbers reduces the perceived Supply Chain Risk.

The individual perception of Supply Chain Risk and the strategic decisions associated with it form the core of this study. Although managers, as professional decision makers, will

normally gather data and evaluate it before making important strategic decisions, the information search and evaluation processes themselves will be triggered off and shaped by individual perceptions of risk. The study seeks to investigate whether individual managers differ in their perceptions of the levels of risk Supply Chains are exposed to, and whether these variances in the perception of risk influence managerial decisions regarding measures of Supply Chain Risk Management. In the theoretical framework, cognitive biases shape risk perception, and the individual risk perception influences investment decisions related to Supply Chain Risk Management.

The unit of analysis in this study is the decision – and more specifically, the decision whether or not to invest in measures of Supply Chain Risk prevention and mitigation.

RESEARCH IMPACT:
The study aims to contribute to understanding of the relationship between cognition and managerial decision making in Supply Chain Risk Management (SCRM). In order to develop a theory about the role of cognitive and behavioural factors in SCRM, theories from psychology and behavioural decision research are applied in an OM context, which currently represents a fairly novel and original approach. In this study, Supply Chain Risk is studied from a behavioural – as opposed to the traditionally structural - point of view, in order to understand how psychological factors influence strategic decisions in SCRM.
The academic contribution of this research on a more general level is that it can provide OM with insights into the human and behavioural element in operations, and inspire further Behavioural Operations research.

PRACTICAL IMPACT:
Inquiry into the role of cognitive biases in Supply Chain Risk perception should increase the understanding of the role psychological factors play in the management of Supply Chain Risk. When supply managers understand how cognitive biases work and how they can be reduced or even eliminated, they will be able to improve the quality of their decisions. This in turn can enable them to increase the effectiveness of their Supply Chain Risk strategies and thus increase the resilience of the Supply Chain.

CONCLUSIONS:
It is evident from the above discussion that there are certain cognitive biases that lead individual managers to overestimate their own knowledge, skills, and their ability to influence circumstances in which they work and make their decisions. This is of particular importance in the management of Supply Chain Risk, as the perception of risk and the decisions how to deal with it are highly dependent on the individual interpretation of the situation and the psychological attitudes of the decision maker.
On an overall basis, the analysis in this study revealed that the four cognitive biases leading to overconfidence and lowered risk perception – illusion of control, overconfidence, planning fallacy and the law of small numbers bias – shape the risk perception in individual supply managers and have an impact on the decisions associated with investments in measures of Supply Chain Risk prevention and mitigation.

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Section 2

Supply Chain Risk Management Frameworks

SCENARIO PLANNING IN SUPPLY CHAIN RISK MANAGEMENT

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ABSTRACT

This paper studies the risks and uncertainties surrounding global food supply chains and finds that "scenario planning" which is a popular tool used in other sectors for risk identification, is less widely used to indentify risks within global food supply chains. Presented in this paper is a review of available literature and a discussion with regards to the feasibility of using scenario planning to address food supply chain risks. The feasibility of using scenario planning at the strategic, tactical and operational level is also discussed.

SUPPLY CHAIN RISK MANAGEMENT

Risk management has become an integral part of a holistic SCM ideology (Christopher and Lee, 2004). Local political turmoil, the ever increasing complexity and uncertainty of weather conditions, terrorism, counterfeiting, and a plethora of other such issues create external risks in the supply chain. The supply chain is also subjected to risks internally. Supplier issues, strikes, quality problems, and logistics issues are more internal operational risks, which need a different level of mitigation. Tang (2006) argues that with so many (e.g. terrorist attacks, hurricanes, earthquakes) disruptions that have happened in recent times, supply chain risk will become an important criterion for cost reduction in SCM. Chopra and Sodhi (2004) classify the supply chain risks in the form of delays of materials from suppliers, large forecast errors, system breakdowns, capacity issues, inventory problems, and disruptions. Whereas, Tang (2006) classifies risks as supply chain risks into operations and disruptions risks. According to Ritchie and Marshall (1993) risks emerge from one of the following sources: (1) Environmental factors (2) Industry factors (3) Organizational factors (4) problem-specific factors and (5) Decision-maker related factors. Tang and Tomlin (2008) recently classified supply chain risks as strategic (long term) or tactical (medium term).

SCENARIO PLANNING

Scenario planning was described by Ringland as a set of processes for improving the quality of educated guesses and also for deciding what their implications are (Ringland, Schwartz 2006). Scenarios were defined by Kahn and Weiner (1967) as "hypothetical sequences of events constructed for the purpose of focussing attention on the causal processes and decision points". Another more recent definition follows (Ringland, Schwartz 2006) "builds plausible views of different possible futures for an organisation based on groups of key environmental influences and drivers of change about which there is a high level of uncertainty" Gerry Johnson and Kevan Scholes (1999). A crucial point noted by many academics is that scenarios are not predictions for the future but rather plausible futures none of which may actually materialise (Wack 1985, Wright 2000). Its purpose is more to make managers more aware of how prepared they are about plausible futures and how these scenarios can assist in making sound management decisions resulting in better and more effective choices (Ringland, Schwartz 2006, Wack 1985). Scenario planning has now being adopted as a planning tool across many organisations but there remains ambiguity regarding the exact procedure and other variables like number of scenarios needed ,number and type of people involved etc. as there is no standard approach towards implementing it.

RESEARCH METHODOLOGY

A survey was conducted in an effort to explore further the understanding and perceptions that entities within the UK food supply chains have regarding supply chain risks and the techniques deployed to mitigate and manage risks and disruptions (Dani and Deep, 2009).

The study was conducted with the help of a confectionary and snack manufacturer. The respondents from the food manufacturer agreed to send the questionnaire to some of the companies within its supply chain. This consisted of upstream suppliers of raw/ finished food products to downstream distribution and logistics providers (including packers). Eight companies in total responded to the questionnaire which was deployed electronically using the 'surveymonkey' website and the question building toolkit. Twenty-eight respondents from the eight companies attempted the questionnaire, of which only fourteen filled it in completely, giving a survey return rate of 50%. Eight respondents from the fourteen were then interviewed for further insight into the risk management process.

DISCUSSION

The study highlighted that 'Loss of reputation' – primarily due to food contamination is the risk that is rated as 'high' and thus needs better 'strategic risk management techniques' to control and mitigate. As shown from this analysis, it is important to note that entities in the supply chain are focusing on operational techniques for risk management, but are paying less attention to 'strategic techniques' which may be needed in the longer term to make risk management a more proactive approach. The respondents also mentioned that the approach towards risk management was more reactive than proactive. Also, risk mitigation is highly dependent on experienced staff leading to knowledge management issues. The strategic risk management processes were conducted every 2-3 years and there was little collaboration with suppliers and hauliers towards risk management. These were important insights which raised a question whether "Scenario Planning should be restricted to a strategic level or brought down to a more operational level?"

SCENARIO PLANNING: STRATEGIC, TACTICAL OR OPERATIONAL?

Scenario planning has traditionally been used for long horizons and as a strategic planning tool primarily amongst large US organisations (Linneman, Klein 1983) and western European organisations (Malaska 1985) and is witnessing a revival in popularity. In a recent survey of UK organisation it was reported that over a third use scenario planning in their strategy workshops (Hodgkinson, Wright 2006). However, more recently there has been a change in the perception of limiting it to long horizons and the interval between its reviews. Healey and Hodgkinson (2008) in their critique of the scenario planning process identifies a potential way to reduce anchoring effects of long term scenarios is to regularly analyse multiple scenarios in a fast and simple manner as opposed to the traditional elaborate and infrequent practice. In a recent paper by Marren (Marren, Kennedy Jr 2010), it is argued that given the increasing level of uncertainty, companies are forced to make critical short term tactical decisions and therefore there is no reason why the scenario approach must be restricted to extremely long timelines. This research aims at combining the strategic scenario planning exercise with scenario based tools at tactical and operational levels with inbuilt feedback and communication processes

SCENARIO PLANNING CONCEPTUAL MODEL

The process for scenario planning for risk mitigation is broadly described in the figure 1. This model is discussed in detail in a separate paper (Deep and Dani, 2009) and is in the process of industrial validation. However, the first and perhaps the most crucial part of the process is scenario planning which is described in this paper.

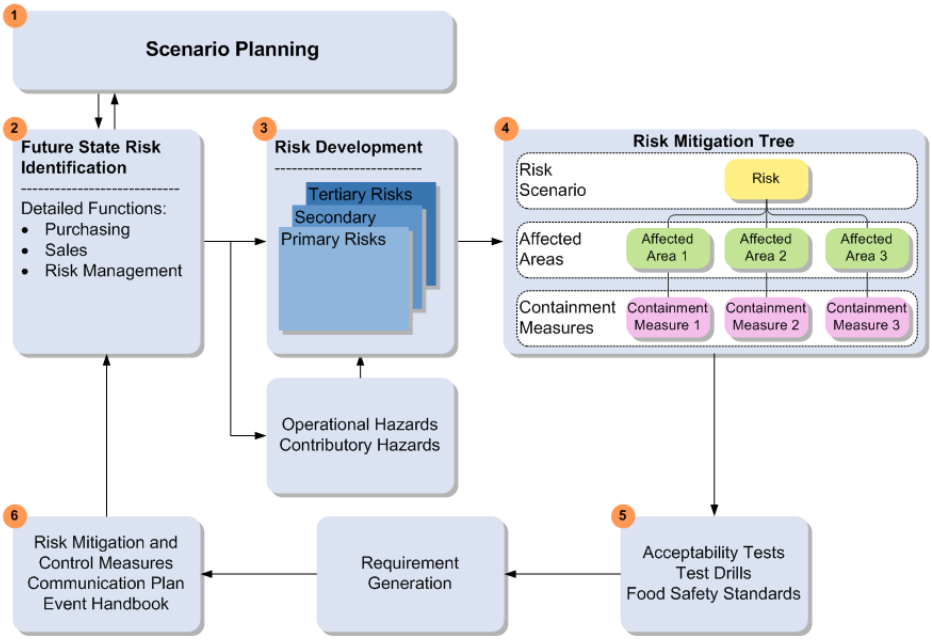

Figure 1: Scenario planning and supply chain risk management

The first step in the toolkit includes an exercise in scenario planning. It is proposed that the scenario building should be done at three levels, operational, tactical and strategic with each feeding into the other. The involvement in terms of team composition should also vary with only Steve's team acting as a common link between the three. Each stage has a set of input and output with the aim of developing a comprehensive scenario at the end (Figure 2)

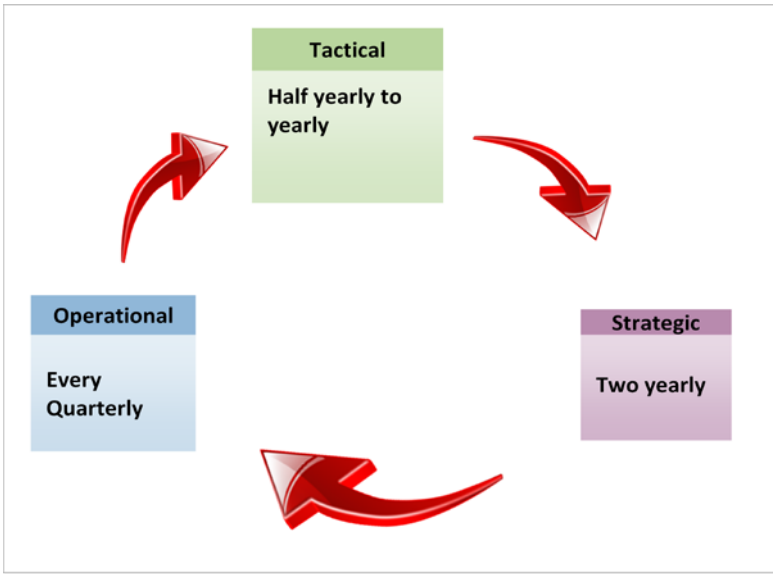

Figure 2: Scenario Planning at three levels

Table 1, depicts the characteristics of the three levels in the process.

	Operational	Tactical	Strategic
Frequency	Quarterly	Half Yearly to yearly	Once in two years.
Members	Middle management from purchasing, distribution ,sales, compliance , warehousing etc	Senior management from sales, hauliage, finance , sales, purchasing etc	Directors of different functions.
Horizon	6months-1Year	2-3 Years	5-10 Years
Questions	Where will we be in the next one year? What is happening to our key performance indicators? Where do we think are our weaknesses?	What will be the logistics structure be like? What will happen to our number of production and distribution sites. Will it go up or down? Where will be expanding internationally? What issues might arise from these changes?	What might the economic landscape look like in the next 5-10 years? What social/technological changes might affect the organisation in the future?

Table 1: the three levels of Scenario Planning

CONCLUSION

The paper presents a study which considers scenario planning as an important process in supply chain risk management. The initial qualitative process has provided insights into the lack of strategic risk planning and the time lag in between scenario planning and risk management. The paper has proposed a scenario planning approach which brings the scenario planning process on an operational level. The framework highlighting the three levels of scenario planning has been tested positively on a limited basis in industry.

ACKNOWLEDGEMENT

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A METHODOLOGY FOR IDENTIFYING, CATEGORISING AND PRIORITISING SOURCES OF SUPPLY CHAIN VULNERABILITY

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ABSTRACT

The aim of this study is to provide organisations with a rigorous methodology for systematically identifying, categorising and prioritising risks within their supply chains. The methodology enables efficient resource allocation for the mitigation and monitoring of supply chain risks. Following a wide ranging review of the supply chain risk management (SCRM) and risk management (RM) literatures, an initial supply chain risk assessment (SCRA) methodology was developed. The methodology was then enhanced and refined through participatory action research studies involving eight blue-chip companies across seven industries. The conclusion drawn is that the SCRA methodology provides organisations a logical process of assessing supply chain vulnerabilities. and can be easily embedded with existing management process of their organisations.

Introduction

Supply chains seem increasingly susceptible to unexpected disruptions. Organisations are not only exposed to internal risks, such as production problems and labour strike etc, but also to network related risks, such as supplier failure and to environmental risks, such as natural disasters and terrorist attacks (Juttner 2005). The recent volcanic activity in Iceland demonstrates how exposed globalised supply chains are to unpredictable events: Nissan suspended production of its Japanese factories for a few days due to shortage of crucial air pressure sensors imported form Iceland; BMW halted production at three plants in Germany for two days due to the closure of European airspace and business continuities of hotels and restaurants in Hong Kong were disrupted due to shortage of French cheese, Belgian chocolates and Dutch Fresh-cut flowers etc.

In such a complex business environment, it has become increasingly clear that traditional risk management approaches do not adequately identify, analyse, evaluate and manage risks across the supply chain. Traditional risk management processes have been refined and applied to SCRM (e.g. Juttner et al, 2003, Harland et al 2003, Gaonkar and Viswanadham 2004, Kiser and Cantrell 2006, Ritchie 2007, Aston Consulting 2008 and Zeng etal 2005 etc), but until recently little attention has been devoted to the questions of how those frameworks can be embedded with existing management process and who would use those frameworks within an organisation.

The proposed SCRA methodology differs from traditional forms of risk assessment which do not take resilience capability of an organisation into account. The SCRA methodology is specifically designed for the senior management team as a risk based method to managing a supply chain, integrating concepts of risk management, supply chain management and resilience management. Its development has been supported through primary research with eight major companies. The methodology typically involves identifying critical entities, assessing the resilience capability of critical entities, identifying risks associated with each critical entity, assessing them in terms of likelihood and magnitude of impact before and after risk mitigation and prioritising risks based on certain hidden factors, criticality of entities, resilience capability of entities and severity of risks in an entity.

RESEARCH APPROACH:

A rigorous research methodology for the development of the SCRA methodology is developed as shown in Figure 1

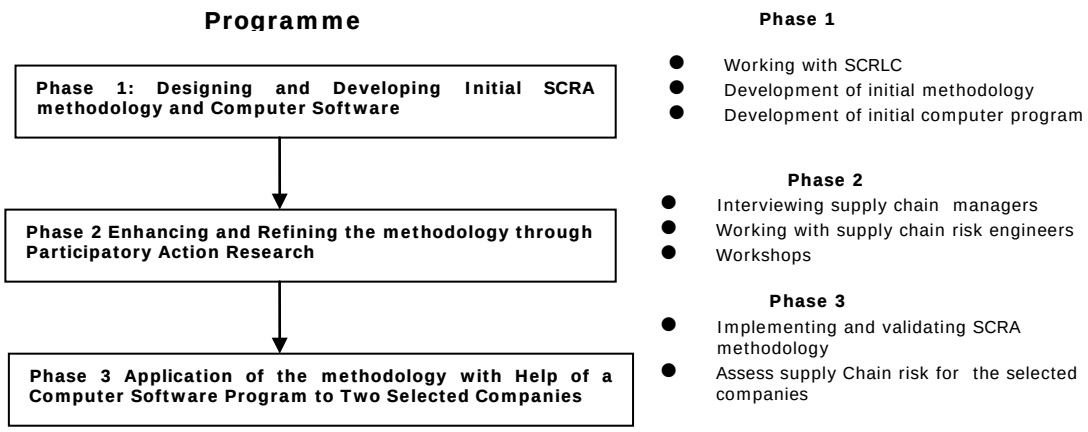

Figure 1: Research Methodology

As a first step towards we conducted a wide ranging review of SCRM and RM literature. The outputs from this review were used to develop an initial SCRA methodology and computer program.

In the second phase, we worked with a small consortium of firms to further enhance and refine the SCRA methodology and computer software program. We were particularly keen to understand how to govern SCRA process at senior management level. Our consortium consisted of eight firms are across seven industries including a government, manufacturing, oil and gas, finance, pharmaceutical, ICT and transportation.

In the third phase, we intend to select two companies and apply the methodology and software to assess their supply chain risks. During the early application (first selected company), it is very likely that some shortcomings of the methodology and software will be identified. Thus it is essential that the researcher responsible for developing the methodology and software is intimately involved in first application of the methodology and software. An important question to address at this phase is: can others actually apply the methodology and software without the original developers. Thus, when assessing supply chain risks for second selected company the researcher will give training to individuals from the company. The company facilitators will then be asked to follow the process as outlined in the handbook as closely as they could but the researcher will offer the support if they need at any stage.

FINDINGS AND ORIGINALITY:

The SCRA methodology is not only coordinated with ISO31000 general risk management standard but also integrated with characteristics of supply chain. It gives firms a sequence to address the key issues within supply chain as shown in Figure 2 in Appendix. The methodology consists of eight major steps and there is a need for expertise to implement the methodology. The output of this process not only provide a firm with important information for monitoring critical risks and their treatment actions but also help a firm restructure its supply chains by analysing risks associated with key design variables.

RESEARCH IMPACT:

The SCRA methodology differs from other risk management approaches in terms of its focus, scope and application. Whereas prior research has generally focused on individual risks, our focus is on the risks as well as the resilience capabilities of organizations within the supply chain. It is a comprehensive method that helps organisations uncover hidden factors that cannot be easily identified by traditional risk management processes and explores interactions among individual risk factors. The framework is specifically designed for management teams at strategic business level or above, which is specified by few models in literature.

PRACTICAL IMPACT:
The development of the framework is fully supported by eight blue-chip companies to ensure practical relevance and ease of implementation. Beneficiaries of the SCRA methodology include supply chain managers, procurement intelligence managers, category managers, contract managers and people from other senior management rather than individual buyers who operate business on day-to-day basis. In addition, it provides firms with:

- A computer software program to assist in the application of the framework
- A validated disruption classification that is mutually exclusive and systematic.
- A method for identifying critical entities
- A risk matrix designed for measuring supply chain disruption
- A resilience scorecard for measure resilience capability
- Means of facilitating risk information sharing among multiple entities
- The first step towards the development of a resilient supply chain.

CONCLUSIONS
Our research builds on the extant literature in several ways. First, few models in literature explore hidden factors which could influence the business continuity of an organisation and interactions among risks factors. The SCRA methodology helps organisation systematically scrutinise multidimensional aspects of supply chain disruptions. It not only uncovers some hidden factors but also explores interactions among individual risk factors, which is particularly useful in making business continuity planning. Secondly, to some extent there has been a disconnection between risk management and supply chain risk management. The SCRA methodology helps supply chain professionals in understanding specific elements of managing risks and risk management professionals in understanding key elements of managing supply chain. Thus, the methodology facilitates both supply chain professionals and risk management professionals to manage supply chain risk together. Thirdly, there are few researches on investigating the effect of supply chain design variables on vulnerabilities within the supply chain. As a result of risk assessment through the SCRA methodology, actionable supply chain design variables can be improved to further enhance the resilience capability of a supply chain. Finally, assessing resilience capability of an organisation is one of the key elements in prioritising sources of supply chain vulnerability in the methodology.

Future research will focus on the implementation of the methodology in order to further test the validity, reliability and applicability of the methodology. The revised process will be tested through two further industrial applications in both the public and private sectors.

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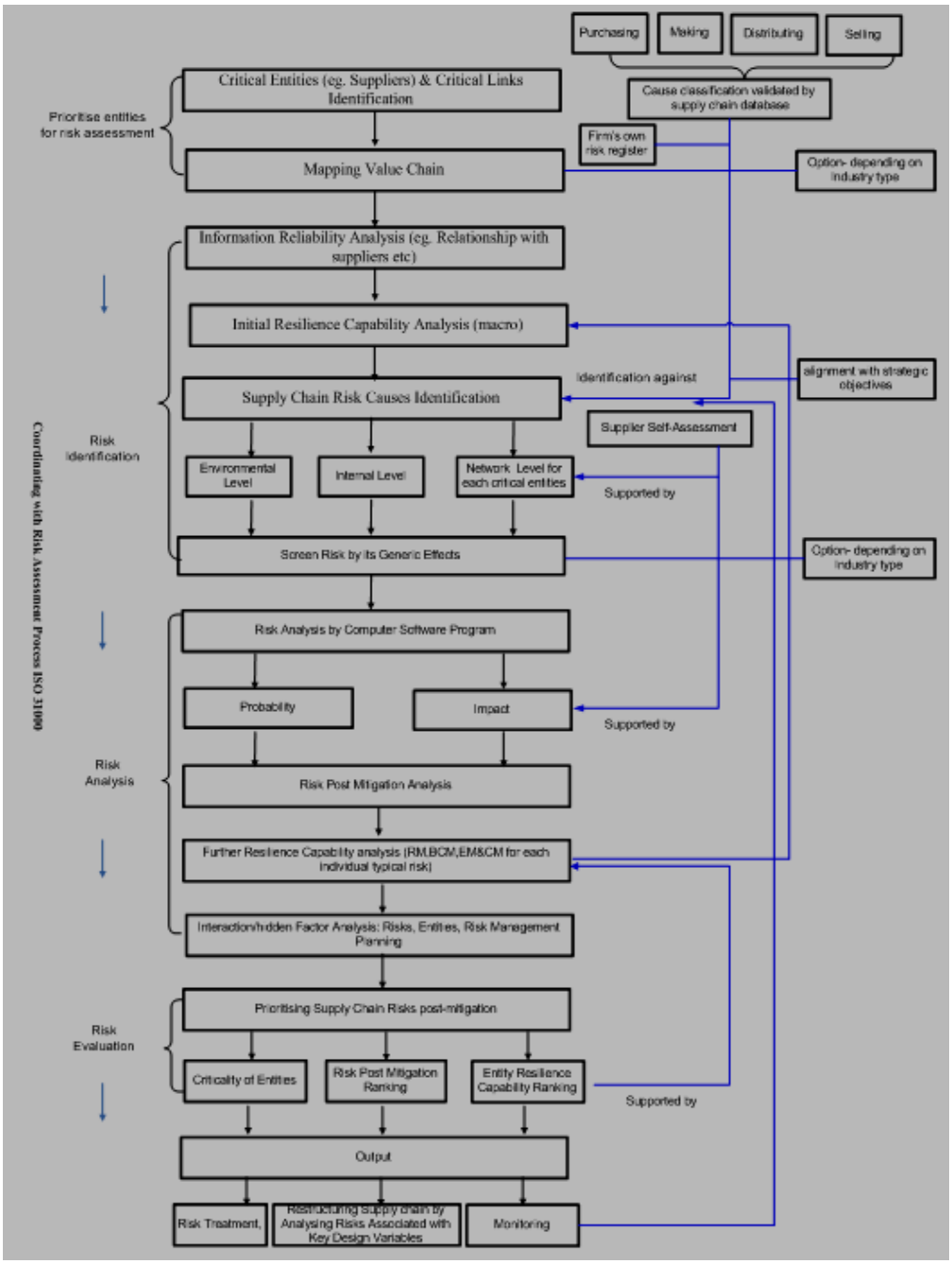
Appendix

Figure 2 SCRA Methodology Process



SUPPLY RISK MANAGEMENT: MOVING TOWARDS A QUANTITATIVE APPROACH

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ABSTRACT
Risk associated with suppliers represents a growing concern, and as a result it has become imperative that firms create resiliency in their organizations and supply chains to ensure business and supply continuity. In this context, this paper lays the foundation for the development of an optimization model for better understanding supply risk and the how the implementation of redundancy and flexibility practices can provide firms greater resilience in their supply chains.

PURPOSE:
Supply chains are becoming more complex with the numerous physical and information flows that involve worldwide companies. To succeed in this environment, firms need to pursue a high level of effectiveness while continuously reducing costs. For this reason, practices such as lean manufacturing, just-in-time and low-cost-country sourcing have become familiar to supply chain managers and have gained growing attention in academia. Nonetheless, if not well designed and managed, these practices can engender potential detrimental consequences due to the risks they induce, which can lead to supply chain disruptions with subsequent financial losses. Among these, the risk associated with suppliers is receiving greater emphasis due to many firms focusing on core activities that increase their dependence on upstream performance, in conjunction with the increasing managers' risk awareness stemmed from the today financial crisis (O'Marah 2009, (Thun & Hoenig 2009). Thus, this study focuses on the supply side of the risk and aims at laying the foundation for the development of a quantitative model that supports supply tactical planning for inbound disruptions and determining the most suitable strategies for ensuring supply continuity.

These inbound disruptions can be caused by environmental events, such as calamitous natural phenomena, or by internal supplier problems, such as poor quality products or delivery delays. An effective supply management strategy should ensure supply continuity. In other words, companies should be able to select the best strategy to increase their resilience (Sheffi & Rice 2005) - the ability to return to the original state or to move to a new and more desirable one after being disrupted (Christopher & Peck 2004). Resilience can be achieved by creating redundancy or increasing flexibility (Sheffi & Rice 2005). Generally, these concepts have been investigated considering the overall company point of view (Christopher & Peck 2004, Peck 2005, Pettit et al. 2010, Sheffi & Rice 2005, Tang 2006), but, since this paper deals with supply risk, we focus the analysis on the upstream flows. In this context, redundancy means keeping some resources in reserve (in terms of inventory, time and capacity) to be used to limiting the consequences of a supply disruption (Sheffi & Rice 2005). On the other hand, flexibility is a more proactive approach and comprises any strategy attempting to reduce the disruption likelihood by increasing the supplier ability to respond in a timely and cost effective manner to changing requirements of purchased components (Tachizawa & Thomsen 2007, Tang & Tomlin 2008). Even though they have been named in several different ways, supply risk management approaches broadly leverage on these two concepts, briefly

described in Table 1 along with their main impacts on focal company and supplier performance and some literature references.

	Strategy	Definition	Impact	References
REDUNDANCY	Inventory buffer	To keep stocks to mitigate risk occurrence	Reduce the impact of supplier delays Increase buffer and total cost Decrease transparency and coordination level	Caputo 1996, Christopher & Lee 2004, , Güllü et al. 1999, Kouvelis & Li 2008, Hung & Chang 1999, Minner 2003, Molinder 1997, Sheffi & Rice 2005, So & Zheng 2003, Van der Vorst & Beulens 2002.
	Time buffer	To include slack time in scheduled time or having longer delivery lead time		
	Capacity buffer	To keep extra internal capacity or have multiple or backup suppliers		
FLEXIBILITY	Supplier integration	To share explicit knowledge or information with suppliers	Increase transparency Improve supplier performance Reduce transaction and acquisition costs Increase plan alignment cost	Bensaou & Anderson 1999, Burke et al. 2007, Caputo 1996, Christopher & Lee 2004, Costantino & Pellegrino 2009, Das et al. 2006, Dyer 1997, Giunipero et al. 2005, Humphreys et al. 2004, Joshi 2009, Krause 1997, Krause et al. 1998, Lee et al. 2009, Modi & Mabert 2007, Sheffi & Rice 2005, Stevenson & Spring 2007, Zsidisin & Ellram 2003
	Supplier development	To share know-how with suppliers		

Table 1 - Overview of flexibility and redundancy practices

Flexibility and redundancy are generally investigated as two different and unrelated practices. In addition, authors studying redundancy practices usually perform quantitative studies in order to identify the optimal quantity to be buffered, while researches on flexibility are more qualitative and descriptive, giving insights into the actual employment of these strategies and their perceived benefits, based on surveys and case studies. To overcome these gaps, we first analyze some of the conjoint effects of redundancy and flexibility practices on the system made up of buyer and supplier (Figure 2). Then, we attempt to quantitatively interpret these relationships, as described in the following section.

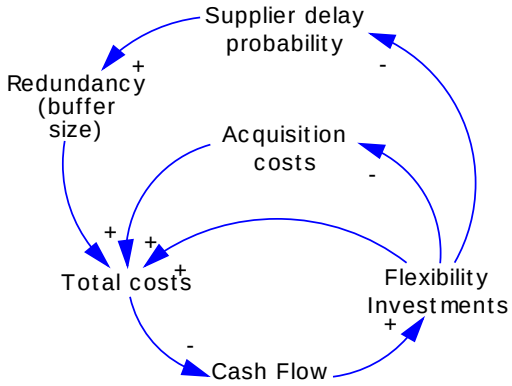

Figure 2 - Conjoint effects of flexibility and redundancy practices

RESEARCH APPROACH:

The qualitative model presented in Figure 2 has been translated in a two stage mixed-integer stochastic programming model (Birge & Louveaux 1997). Due to space constraints, we report only the description of the model without the analytic formulation. In a two-stage stochastic optimization approach, the uncertain parameters are considered as random variables with an associated probability distribution and the decision variables are classified into two stages. The first-stage variables correspond to those decisions that need to be made prior to the realization of the uncertainty. The second-stage corresponds to those decisions made after the uncertainty is unveiled. After the first-stage decisions are taken and the random events realized, the second-stage decisions are subjected to the restrictions imposed by the second-stage problem. Due to the stochastic nature of the performance associated with the second-stage decisions, the objective function,

traditionally, consists of the sum of the first-stage performance measure and the expected second-stage performance.The objective of the stochastic model is to support the selection of the best medium/long term strategy (or mix of strategies) among those available, considering the impact of possible risky events that could affect the inbound flow. In particular, we consider only the risks that affect the incoming product availability and delivery timeliness, while we purposely neglect those ones that cause uncertainty in terms of the price to be paid for inbound supplies, such as price volatility and currency rate fluctuation.

Thus, the main consequences of a supply risk occurrence can be classified as follows:

- *Delay*: supplier delivers late the entire quantity ordered.
- *Short-shipment*: supplier delivers on time only a portion of the order and the remaining quantity is delivered at a later time.
- *No shipment at all*: all the quantity ordered is lost and no more order can be placed to this supplier because it does not provide supply anymore. There can be several reasons for this, such as natural disaster, going out of business, being bought out by another firm, changing the direction of its business and customer market, or determining that the customer is no longer profitable.

This classification contemplates also quality problems and wrong part deliveries. In fact, both cases require supplier intervention in order to repair or substitute the defective/wrong products and this can result in a delay in the final delivery.

Considering these risk occurrences and an uncertain demand, the objective of this model is *(i)* to define the optimal number of suppliers to deal with among a supply base composed by *M* suppliers, *(ii)* select the best strategy (or mix of strategy) to be implemented (in terms of redundancy practices and flexibility investment) and *(iii)* allocate the needed quantity to the selected supplier(s) in order to negotiate a framework agreement.

Flexibility practices generally require substantial investments in the buyer-supplier relationship and, for this reason, a proper assessment of supplier characteristics and the external environment should be carried out. In particular, research findings suggest that investments in suppliers make sense when there is a significant impact of the delivered product on company profitability (Cannon & Perreault 1999, Handfield & Bechtel 2002, Kraljic 1983, Krause 1999, Leeuw & Fransoo 2009, Modi & Mabert 2007), high supply market complexity (characterized by low number of suppliers available, high customization level, high technological level and so on) (Bensaou & Anderson 1999, Giunipero et al. 2005, Hallikas et al. 2004, Kraljic 1983, Lee et al. 2009, Leeuw & Fransoo 2009) and high importance and capability of the supplier (Bensaou & Anderson 1999, Humphreys et al. 2004, Krause 1999, Leeuw & Fransoo 2009). Consequently, the supplied items in this model cannot be commodities but should be some custom products with the above mentioned characteristics. Based on this assumption, when the buying company selects a specific supplier it also signs a framework agreement with it, meaning that the two companies define a quantity *X* (called committed or contracted quantity) that should be ordered over the entire planning horizon.

We also assume that each supplier is characterized by an acquisition cost, an urgent shipment cost (in case of emergency, the buying company could require some shipments with a shorter lead time but higher cost), a fixed cost, a lead time, a given probability to delivery late all the quantity ordered or only a portion of the order, and a given probability to not ship at all the required order. When the buying firm decides to make an investment to improve supplier flexibility, the fixed cost associated with the supplier will increase, including also the investment cost. The acquisition and expediting costs, and the probabilities that the supplier will be late or will not ship at all should decrease. These reductions will depend on the type and amount of investment and should be assessed before running the model. In summary, the quantitative model is divided in two stages, each of which has different decision variables.

First Stage: Before the beginning of the planning horizon and then before the uncertainties are discerned, the buying company has to define whether to sign a framework agreement with one or more suppliers, or to invest in one or more suppliers in

order to increase their flexibility and subsequently their reliability (decreasing delay and supplier loss probability). In both case the buying company should also determine the total quantity that should be ordered during the entire planning horizon from each selected supplier. This decision should be made considering the fixed and investment cost associated with each supplier and the second stage expected cost.

***Second stage**:* During the planning horizon the uncertain parameters become known, which include on time and completeness of supplier delivery, loss of suppliers, and actual demand. In this stage, we will define *k* scenario for each of them with an associated probability p_k to occur.

The second stage decision variables are the quantity to be ordered each period for each selected supplier and the frequency of urgent orders. These decisions should be determined based on inventory/backlog costs, acquisition cost and expediting costs. However, the main objective of this second stage is not to define the right quantity to be ordered each time (this would be the aim of a following operational planning), but is to define the theoretical optimal quantity to be ordered in each scenario in order to calculate the expected cost allowing to select the best strategy and the contracted quantity.

FINDINGS AND ORIGINALITY:

As mentioned above, flexibility and redundancy practices are usually presented in isolation. However, since flexibility and redundancy are mutually dependent practices, a systemic approach that analyzes the system holistically (de Rosnay, 1997) is considered by the authors more appropriate to describe the impact of these risk management practices on supplier and buying company performance. In this regard, this study represents an attempt to analyze supply risk management following a systemic approach, with the main differences between analytic and systemic approaches being presented in Table 2.

Analytic approach	Systemic approach
Isolates elements	Unifies elements
Emphasizes the precision of details	Emphasizes global perception
Focuses on one variable at a time	Focuses on groups of variables simultaneously
Validates facts by means of experimental proof within the body of a theory	Validates facts through comparison of the behaviour of the model with reality
Deals with linear and weak interactions	Deals with non-linear and strong interactions

Table 2 - Analytic vs. Systemic approach

RESEARCH IMPACT:

From a research point of view, this stochastic model contributes to fill the gap identified in the first section and, then, to propose a more comprehensive and quantitative model to evaluate the economic advantage of investing in suppliers to increase their flexibility. Further, this model evaluates the impact of investments on redundancy practices, which include inventory, time, and capacity. In addition, through a sensitivity analysis of the results, it will be possible to better understand when and under which conditions flexibility practices are useful to reduce the total cost. Finally, considering the option of vertical integration, this tool can provide some evidence of the impact of supplier reliability on make or buy decisions.

CONCLUSIONS:

This model, through a two stage stochastic programming, aims at support the tactical supply planning of a firm when it comes to decide the best strategy to be implemented considering supplier-oriented risk. Since it is an Operational Research model, the main limitation is that all the qualitative factors that can influence strategy selection process should be translate in monetary value. Furthermore, this model takes into account flexibility only from supply point of view, without considering any other possible intervention on the internal or downstream processes to increase resilience.

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ASSESSING SUPPLIER DEFAULT RISK ON THE PORTFOLIO LEVEL: A METHOD AND APPLICATION

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ABSTRACT

The main purpose of this paper is to quantify the risk in a buying firm's supplier portfolio that stems from the financial default of suppliers. Based on credit risk models we develop a methodology that buying firms can use to determine their exposure to supplier default risk. Empirical data pertaining to supplier portfolios of upper-class car models from three German automotive manufacturers is used to illustrate the application of the methodology. We show that some car models are exposed to higher risk. This places them at a disadvantage, because the higher the supplier default risk, the more likely it is that the supply of components can be disrupted and cars cannot be built and sold. Buying firms can use this methodology for the pro-active assessment of supplier default risk.

PURPOSE

To date, the assessment and quantification of supplier default risk that goes beyond the analysis of supplier firm ratings (such as the ratings provided by Standard & Poor's, Moody's, or Fitch) has remained largely unexplored. Reasons are that the prediction of the behaviour of firms that are connected in a supply network is complex and that supplier defaults are correlated and not independent events (Wagner, Bode, & Koziol, 2009). Furthermore, firms do not have outright access to data for the assessment of supplier default risk. In consequence, there is a lack of quantitative models for the systematic quantification of supplier default risk. Therefore, the first goal of this paper is to develop a method based on portfolio credit risk models that can be used to assess supplier default risk. Consistent with the extant literature that buying firms need to manage the risk in their supplier portfolio (as opposed to managing the risk of individual suppliers) (Choi & Krause, 2006; Wagner & Johnson, 2004), the proposed method can be applied on the portfolio level. The second goal is to exemplify the application of the method by analyzing real-life supplier portfolios and assessing and comparing the default risk inherent in these portfolios.

RESEARCH APPROACH

In finance, various models for investment risk quantification and management have been developed. For example a bank determines the price of a loan mainly based on expected loss. The unexpected loss in a loan portfolio should be captured by economic capital, as Basel II regulation requires. For the purpose of this study, we use the Bernoulli model as a basic approach of modelling defaults and the more advanced CreditRisk+ model, which was initially developed by CreditSuisse First Boston in 1997 (Wilde, 1997). The latter is a widely used and well accepted method for risk quantification.

Essential risk attributes of counterparties

Default probability. The default probability (DP) of a firm represents the probability that the firm goes into bankruptcy in a certain time period, typically one year (Bluhm, Overbeck, & Wagner, 2002). Two approaches can typically be used to assign the DP to a firm. The first approach is *using market data of the firm to calculate the DP*. This approach is supported by previous research and finds its applications in various industry models. Altman (1968) shows the efficiency of predicting firm's bankruptcy by multiple discriminate models using financial ratios, for example liquidity ratio and leverage ratio. Jarrow and Turnbull (1995) propose a method of estimating default risk using the price of corporate bonds. In the well-known KMV credit risk model, the DP is defined in the content of an asset value process. The DP is the likelihood that the assets value of the firm becomes lower than the critical threshold in a certain period of time, usually one year (Bluhm et al., 2002). The second approach is to *calculate the DP with ratings from rating*

agencies like Moody's, Standard & Poor's, or Fitch. The rating agency measures the credit worthiness of a firm and assigns a rating to the firm which is expressed in a letter system. The transformation from the letter system of the rating to the DP can be done using historic default frequencies, for instance the Moody's historic bond default frequencies for Moody's ratings.

In the first approach for obtaining DPs, collecting market data of the firm and modelling the DP has to be done by the researcher. In the second approach, the analysis of the firm is done by rating agencies. The advantage of the second approach is that it requires apparently less effort for data collection and analysis. One disadvantage of ratings is that rating agencies only rate a limited number of firms. For example worldwide only 59 automotive suppliers were rated by Moody's in the year 2009 (Harrod, 2009). For firms that are not rated, other methods such as peer-group analyses are required. Another disadvantage of ratings is that they are not transparent and may lead to misunderstanding. The ratings may not be reliable. For the purpose of this study we opted to use the second approach, by using the individual DPs of automotive suppliers from a rating evaluation.

Exposure at default. In banking the exposure at default (EAD) of an obligor contains two parts: drawn (OUTST) and undrawn loan (COMM) at the time before default, where $\mathrm{EAD} = \mathrm{OUTST} + \gamma * \mathrm{COMM}$ and γ is the expected portion of the commitments likely to be drawn prior to default. An approach to determine "exposure at supplier default" would be to measure exposure as a dollar value. There are situations in purchasing where a dollar value of an exposure can be estimated. For example, in the raw material spot market the buyer can switch from a contracted supplier to a spot market to satisfy its demand. Haksöz and Kadam (2009) argue that in the setting above, the exposure at contract breach by a supplier is the difference between the spot market unit price and the contract unit price multiplied by the volume of the contract. However automotive parts, components, modules or systems are regularly customer-specific or even car model-specific, so that spot markets with price information do not exist. In case of a supplier default, the OEM cannot turn to the spot market and maybe just pay a higher price. The exposure at supplier default is an ex post measurement which is difficult to forecast accurately. However, OEMs might financially assess exposure (e.g., a simple way would be to use purchasing volumes for the components) and estimate and assign a dollar value for exposure to each supplier.

Besides the availability of such information, another difficulty is that supplier defaults are rare events and empirical reports of the loss from defaults are often not available. Nevertheless, one can identify determinants for defaults (e.g., complexity of the components, availability of suppliers, ease of switching suppliers) and derive a quantitative measure for exposure (on a scale other than dollar value), and use this information in the credit risk model.

Expected loss of single default. In the banking industry the expected loss of an obligor is measured in the following way: the bank assigns to a obligor denoted as i a default probability (DP), a exposure at default (EAD) and a loss fraction called the loss given default (LGD), describing the fraction of the exposure subject to be lost in the considered time period (Bluhm, Overbeck, & Wagner, 2003). The loss $\tilde{\mathrm{L}}$ of the obligor is defined by:

$$\tilde{\mathrm{L}}_{\mathrm{i}} = \mathrm{EAD}_{\mathrm{i}} * \mathrm{LGD}_{\mathrm{i}} * \mathrm{L}_{\mathrm{i}} \text{ with } \mathrm{L}_{\mathrm{i}} = 1_{\mathrm{D}}, \mathrm{P}(\mathrm{D}) = \mathrm{DP}_{\mathrm{i}}$$

where D denotes the event that the obligor defaults in a certain period of time (most often one year). L_{i} is a Bernoulli random variable and $\mathrm{P}(\mathrm{D})$ denotes the probability of D. The expectation of any Bernoulli random variable 1_{D} is its event probability.
The expected loss (EL) of the obligor as the expectation of its corresponding loss variable $\tilde{\mathrm{L}}$ is determined by:

$$\mathrm{EL}_{\mathrm{i}} = \mathrm{E}[\tilde{\mathrm{L}}_{\mathrm{i}}] = \mathrm{EAD}_{\mathrm{i}} * \mathrm{LGD}_{\mathrm{i}} * \mathrm{P}(\mathrm{D}) = \mathrm{EAD}_{\mathrm{i}} * \mathrm{LGD}_{\mathrm{i}} * \mathrm{DP}_{\mathrm{i}}$$

In this study the loss due to a supplier default for one OEM is similar to the obligor default in banking. The methods to calculate the loss in a credit risk model are already well established. The expected loss is also calculated according to last equation above.

Default correlation. Similar to the correlation between obligors in a loan portfolio, recent studies have shown that the defaults of suppliers in a portfolio can also be correlated (Babich, Burnetas, & Ritchken, 2007; Swinney & Netessine, 2009; Wagner et al., 2009). Default correlation between firms in credit risk modelling should be the same from a bank and from an automotive OEM point of view. There are well established explanations about correlation in the credit risk modelling research, for instance the state of the overall economy or the situation in the particular industry. Correlation modelling is an important and challenging part of credit risk modelling. One basic idea is to treat default probabilities as random variables. The default frequency of companies in the same rating class can vary from year to year. In the Bernoulli model the default correlations are fully captured by the covariance structure of the stochastic default probabilities. In the CreditRisk+ model the correlation is introduced by randomization of default intensity and sector analysis (Wilde, 1997).

Empirical setting

We have chosen the German automotive industry for our empirical analysis for various reasons. It is a well known and important industry in many countries, particularly in Germany. Also, automotive OEMs are highly dependent on their suppliers. On the one hand, automotive OEMs are large and powerful customers, on the other hand, suppliers are critical for automotive OEMs to achieve and sustain competitive advantage due to the high degree of outsourcing and the innovation that comes from the suppliers. The high criticality of suppliers for the OEM's success coupled with frequent supplier defaults observed in the industry warrants an investigation of supplier default risks which can inform industry practice and research.

The database "Who Supplies Whom" published by SupplierBusiness, a research company focusing on automotive supply base issues, was used to obtain comprehensive information about current car models, components, and modules as well as suppliers. Based on this information, we constructed and analyzed supplier portfolios for three upper-class car models which have similar target customers and belong to a similar price range: the BMW 5-series (platform: E60; launch: 2003), the Audi A6 (platform: C6; launch: 2004), and the Mercedes E-class (platform: W211; launch: 2002).

Company ratings and default probabilities were obtained from the AMADEUS (Analyse MAjor Databases from EUropean Sources) data base provided by Bureau van Dijk-Electronic Publishing. AMADEUS focuses on European companies and provides standardized annual reports (for up to 10 years), and financial ratios as well as information on business activities and ownership structures on approximately 11 million companies throughout Europe. AMADEUS also offers a rating – the MORE (Multi Objective Rating Evaluation) rating, a credit risk product from ModeFinance. The MORE rating is used for obtaining default probabilities.

As discussed earlier, exposure is difficult to measure in the automotive industry. Therefore, we have chosen switching costs as a proxy for exposure. While exposure measures the value subject to loss at default, switching costs measure the cost of switching away from a supplier after a default. Both concepts are part, component, module, system, and supplier market specific. Estimating a dollar value of switching cost of a certain component is almost impossible for a broad range of components. Therefore, we aimed at assessing how difficult it is to switch away from a supplier of a certain component. Based on a standardized questionnaire, multiple experts were asked to estimate the switching cost for each component on a five-point rating scale (1: very low, 2: low, 3: medium, 3: high, 5: very high), which we denoted as switching cost rating (SCR). Thus, it is important to note that these "switching costs" are measured on an arbitrary unit. It is not a monetary value as in the common credit risk distributions. And an assumption made is that the switching cost ratings of suppliers are linear; hence it is allowed to add the switching cost of suppliers together. This assumption is necessary to justify the use of switching cost ratings as exposures. We selected two informants that were familiar with the supply markets and the components provided to automotive OEMs.

The switching cost rating of the individual components received were transferred to a switching cost rating. Since the unit of analysis in the CreditRisk+ model is the individual supplier, not a component, it was necessary to aggregate the SCRs of the components to that of the supplier. For suppliers supplying multiple components there are three different possibilities to calculate the SCRs of suppliers from the SCRs of the components:

- SCR of supplier = Sum of SCRs of all components in the supply scope (scenario I)
- SCR of supplier = Mean of SCRs of all components in the supply scope (scenario II)
- SCR of supplier = Max of SCRs of all components in the supply scope (scenario III)

Scenario I assumes that the SCRs of components are linear and can be added together. On the one hand, this assumption seems to be reasonable, as the more components the supplier delivers, the higher the switching cost. But on the other hand, the assumption has a disadvantage. If one supplier delivers five very simple components, all with SCR of 1, the supplier has finally a SCR of 5, which is equal to a supplier which delivers a very difficult component with SCR of 5. This may not be the case in reality. Following scenario I the supplier can receive a SCR bigger than 5.

Scenario II takes the average value of SCRs of all the components in the supply scope as the rating of supplier. In this case, the disadvantage of adding up the ratings in scenario I is avoided. If a supplier supplies 5 components with SCR of 1, the supplier receives a SCR of 1. Following scenario II the supplier SCR ranges from 1 to 5.

Scenario III assumes that the most difficult component to replace in the supply scope is decisive for the SCR of a supplier. For instance, if one supplier delivers two components, one with SCR of 4 and the other with 3, the supplier receives a SCR of 4. Similar to scenario II, the supplier SCR is also between 1 and 5 under scenario III.

FINDINGS AND ORIGINALITY

We analyze the supplier portfolios for the three car models BMW 5-series, Audi A6, and Mercedes E-class. We demonstrate how the Bernoulli model, a Bernoulli mixture model, and the CreditRisk+ framework can be applied to the gathered data. The results provide various information which support the automotive OEMs in supply chain risk quantifications and management from various aspects.

PRACTICAL IMPACT

In this paper, credit risk models are introduced to the supply chain context to quantify supplier default risk. The Bernoulli model and the CreditRisk+ model are examined for their applicability. First of all, the credit risk models provide the buying firm a new perspective and an integral framework for analyzing the different risk aspects of the supplier portfolio, mainly the default probabilities and exposure of suppliers and the default correlation structure among suppliers. Hence the first important message from the models is that knowing the suppliers is important. OEMs should pay attention to the risk attributes of the suppliers, for instance the financial health of the supplier, the availability of alternative suppliers and so on. The data collection process itself enables the OEM to know its own supplier portfolio better in a systematic way. Based on the collected data, the OEM may keep a watch list of suppliers which have high default probability in the next year. The OEM may also analyze the suppliers with very high exposure and identify them as strategic partner or consider the development of alternative suppliers.

Second, the outputs of the models may support various decision making processes in supply chain risk management. With the default event distribution and the loss distribution of the supplier portfolio, the OEMs can plan its human and capital resources more efficiently. For instance, if the analysis shows that the default risk of the portfolio is high in the next year, it is perhaps advocated to invest more resources in managing the supplier base, enhancing supplier development or switching away from a supplier with high default probability. The portfolio loss distribution supports buying firms in creating risk mitigation strategies, for example buying insurance. The risk contribution of each supplier from the CreditRisk+ model advocates risk-benefit balance thinking in supplier evaluation processes and assists the portfolio management, for instance reducing the portfolio extreme loss by removing suppliers with high risk contributions.

CONCLUSIONS

Advanced credit risk models can be adapted to assess supplier default risk. As the application of credit risk models requires a large amount of information on the suppliers, the buying firms (including OEMs) are in the best position to do the analysis. The analysis process may become a tool for OEMs to quantify and manage supplier default risk. The models can also be applied to other industries where the buying firm is concerned about risk of supplier defaults.

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SUPPLY CHAINS RISKS: A SYSTEMS THINKING PERSPECTIVE

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ABSTRACT

This paper considers a systems perspective towards managing these risks. It presents variables that may affect next generation supply chains and applies a causal loop model towards depicting the causal linkages of these variables with future supply disruptions. The causal linkages between the variables are then highlighted with regards to the supply chain process and the nodes, and the causes of future risks are identified. From the causal loop diagram the risk propagation is derived in a form of risk framework.

SUPPLY CHAIN RISKS

Risk management has become an integral part of a holistic SCM ideology (Christopher and Lee, 2004). Supply chains are increasingly challenged in today's global world due to uncertainties in supply and demand, shorter product and technology life cycles, the globalised market and changing environmental conditions. Tang (2006) argues that with so many (e.g. terrorist attacks, hurricanes, earthquakes) disruptions that have happened in recent times, supply chain risk will become an important criterion for cost reduction in SCM. Chopra and Sodhi (2004) classify the supply chain risks in the form of delays of materials from suppliers, large forecast errors, system breakdowns, capacity issues, inventory problems, and disruptions. Whereas, Tang (2006) classifies risks as supply chain risks into operations and disruptions risks. According to Ritchie and Marshall (1993) risks emerge from one of the following sources: (1) Environmental factors (2) Industry factors (3) Organizational factors (4) problem-specific factors and (5) Decision-maker related factors. Tang and Tomlin (2008) recently classified supply chain risks as strategic (long term) or tactical (medium term). Zsidisin (2008) have attempted to identify risks for the aerospace industry. There are several other classifications of supply chain risks (Sinha et al., 2004; Finch, 2004; Norrman and Lindroth, 2004; Kleindorfer and Saad, 2004; Manuj and Mentzer, 2008; Wu et al., 2006) available in literature.

RESEARCH METHODOLOGY

The research was conducted to understand the factors that would affect next generation supply chains. It was also necessary to understand how these factors would lead to risk propagation through the supply chain. The basic assumption considered was that all the identified factors will lead to some risk in the supply chain. To understand the interdependencies within these factors and the risk propagation on account of these factors it was decided to adopt a systems perspective. This perspective is based upon application of a causal loop diagram which considers the interdependencies between the factors affecting next-generation supply chains. The causal linkages between the variables are then highlighted with regards to the supply chain process and the nodes and causes of future risks are identified. Using the causal loop diagram, a risk framework is developed for next generation supply chains showing the impact of the risk. This is checked with some instances of risk propagation within the aerospace sector.

SYSTEMS THINKING

Systems of Systems (SOS) are large scale concurrent and distributed systems that are comprised of complex systems (Kotov, 1997). The Systems of systems concept originally evolved in the defence sector, but now it being widely spread globalised in all sectors. In today's world early identification and management of the supply chain risks that could affect product and/or service quality becomes increasingly necessary. Oehmen et al. (2009) has developed supply chain risk models to identify possible dynamics of the risk development. The systems thinking perspective adopted in this research focuses on understanding how the physical processes, information flows and managerial policies interact so as to create the dynamics of the variables of interest. Supply chain is similarly

such a complex system consisting of a complex network of stakeholders and their dynamic interrelationships. Supply chain risk management ensures the continuous success of customers supply base by delivering products and/or services in accordance with set quality standards. Figure 1 represents the system of systems approach to a typical supply chain network showing the hub and spoke structure of supply chain system and interrelating network links within supply chain entities. The figure presents supply chains as a complex network of entities from the perspective of inter-related risks which can cause the flow to disrupt.

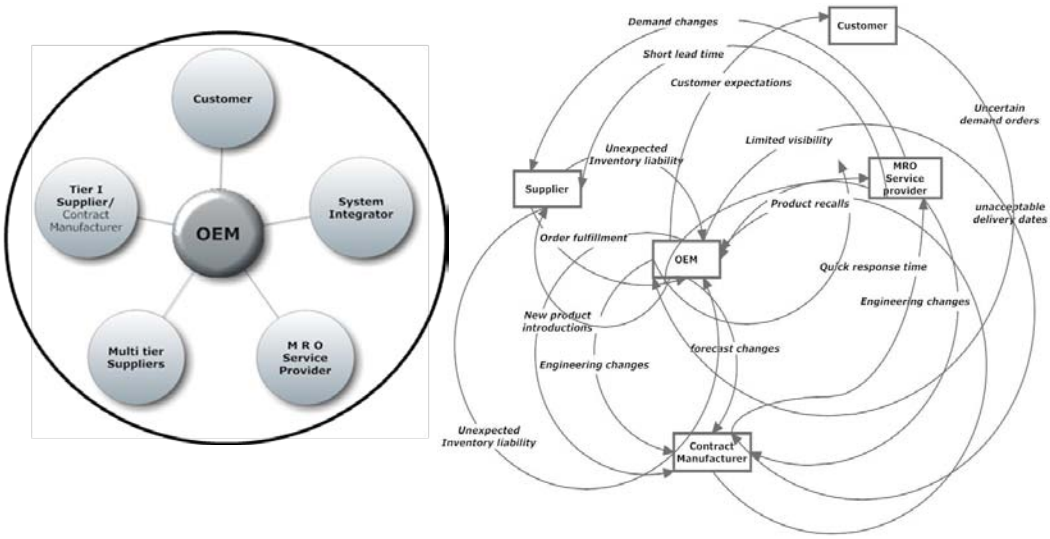

Figure 1 Typical supply chain behaviour from a systems perspective

In next section, Using systems thinking, interactions of its variables through feedback loops are captured, where a change in one variable affects other variables over time, which in turn affects the original variable. We identify and define the problem in terms of risks arising due to internal and external factors within supply chain observed from sustainability perspective.

NEXT GENERATION SUPPLY CHAIN RISK VARIABLES: CAUSAL RELATIONSHIP

Causal loop diagrams are the basis on which the SD model is built. They depict, graphically, the interactions and cause-and-effect relationships among the different system parameters (Lertpattarapong, 2002). During the model development, Causal loop diagrams serve as preliminary sketches of causal hypotheses and they can simplify the representation of a model. The structure of a dynamic system model contains stock (state) and flow (rate) variables. Stock variables are the accumulations (i.e. inventories), within the system, while flow variables represent the flows in the system (i.e. order rate). The model structure and the interrelationships among the variables are represented by causal loop diagrams. The Next generation supply chain issues were identified from various workshops conducted as a part of NEXGEM workshops and an extensive literature review. Following are the identified issues for next generation supply chain:

1. Environmental regulations
2. Information and communication technology
3. 3PL/4PL Logistics service
4. Global market
5. Customer expectations
6. Skills shortage

Figure 2 shows the causal relationship of identified next generation supply chain issues with risk assessment parameters.

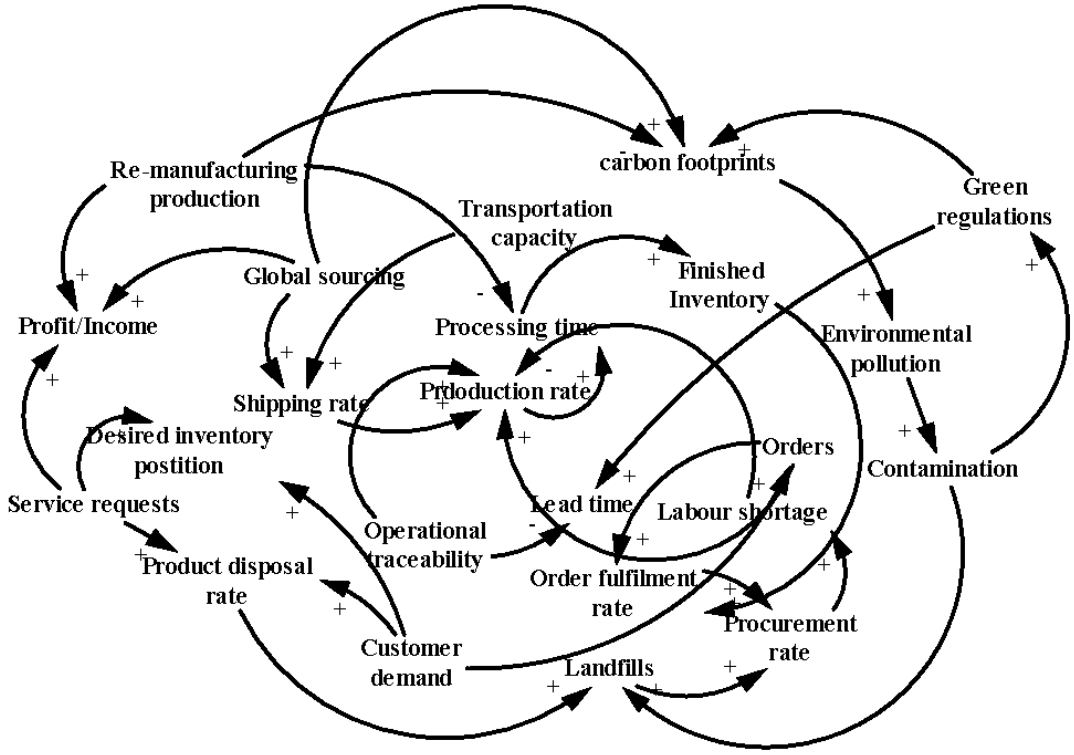

Figure 2: Causal loop diagram for supply chain system (Ghadge, Dani and kalawsky, 2010)

With reference to the causal model, it can be inferred that this is not complete. Supply Chains are dynamic and as factors change, the risk parameters will modify and propagate. It is important to get a perspective to initially understand the system and then create the capability to dynamically modify it. From the causal loop diagram above, the risk propagation is derived in a form of risk framework as shown in figure 3.

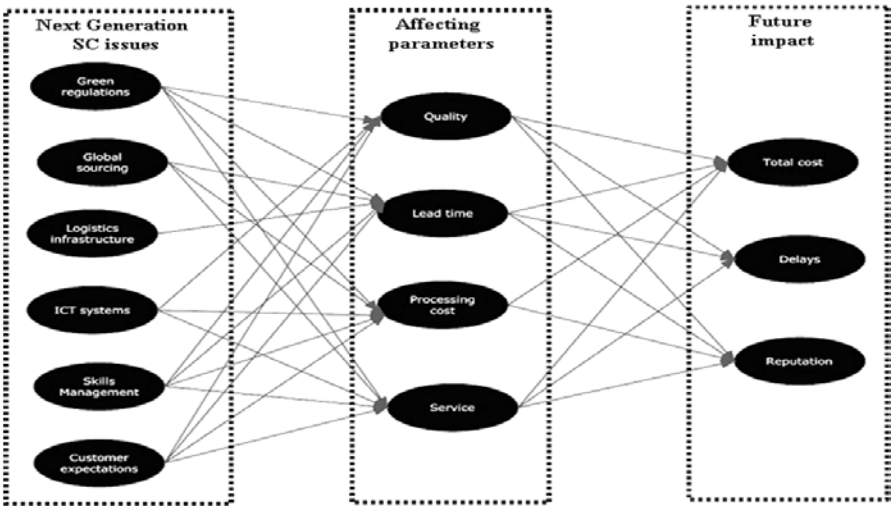

Figure 3: Next generation supply chain risk framework (Ghadge, Dani and Kalawsky, 2010)

Research impact

The research has focussed on literature and case examples derived from literature sources. The causal linkages between the next generation supply chain variables is highlighted with regards to the supply chain process and the nodes and causes of future

risks. Using, the causal loop diagram a risk framework is developed for next generation supply chains showing the impact of the risk.

Practical impact

The outcomes of this study will help researchers and managers to identify next generation supply chain risks (which is based on variables, such as: green sc, lack of skills, role if technology, etc.). This research presents a new method for managers to consider their supply systems and map out the future risks. This will then help to implement a proactive approach towards managing risks within the Supply chain network.

CONCLUSION

The research approach for the paper is based upon application of systems engineering thinking to understand supply chain systems and identify various risks associated with in the closed loop supply chain network. Outcomes of research will help academicians and practitioners to gain insights into risks seen from systemic perspective and will guide them in developing simulation models for future supply chain management. The Risk framework is in its infancy and needs further testing and would be developed further as a future work.

ACKNOWLEDGEMENT

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INTEGRATING SUPPLY CHAIN RISKS IN PRODUCT DEVELOPMENT: A CONCEPTUAL FRAMEWORK

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ABSTRACT

This paper develops a conceptual framework for integrating supply chain risks in product development. To achieve this goal, existing generic PD processes are integrated and augmented to emphasize the early phases of the development process. This extended generic PD process consists of five elements of portfolio management, project management, contracting & business case, technology development and design. In the next step, various risk management frameworks are reviewed and the ISO 31000 risk management standard is adapted to application in PD. It is then integrated with the previously developed generic PD process.

Based on this conceptual framework, we identify supply chain risks that originate in the five different stages of the generic PD process. Among those risks are different forms of dependency on suppliers; increased complexity of the supply chain; and misaligned incentives of key stakeholders.

The tool could be useful for managers working in supply chain and/or product design to identify and manage their risks. The theoretical contribution is a wider understanding of issues emerging from the integration of PD, RM and SCM.

PURPOSE

A number of recent case studies have illustrated the strong influence that decisions during the development of a new product have on supply chain risks. Among these examples from industry are the continuing delays of the Boeing 787 Dreamliner (Tang and Zimmerman, 2009), cost overruns of a large number of development projects for the US Department of Defense (GAO, 2010), overdependence on global suppliers (Oehmen et al., 2009) and lack of responsiveness in the textile and apparel sector (Khan and Creazza, 2009). These cases reinforce the notion that “the supply chain begins on the drawing board” (Khan and Creazza, 2009) and that the early stages in the development process are particularly important.

However, several shortcomings exist in the current literature regarding the management of supply chain risks originating in the PD process: i) existing generic PD processes do not place emphasize on the pre-design activities, such as technology development and contracting, as well as on important higher-level management activities, such as portfolio and project management; ii) there is no risk management process that addresses the full scope of product development – from a high-level portfolio management to the final design phase; iii) supply chain risks are not systematically addressed in PD.

The purpose of this paper is to introduce a conceptual framework that consists of a generic PD and risk management process. It overcomes the above mentioned shortcomings by extending the scope of the existing PD processes, leading to a comprehensive risk management process. This framework is then used to identify and discuss how decisions in product development influence supply chain risks.

RESEARCH APPROACH

This paper is based on a review of the literature in the areas of PD processes, RM processes with application to PD, as well as a review of case studies on supply chain risks that are related to PD. We have adopted a theory building approach to develop our conceptual framework and verified it by applying it to existing case studies to illustrate the relationship between decisions in PD and SC risks.

FINDINGS AND ORIGINALITY

A number of generic PD processes can be found in the literature. Among the most highly cited examples are the following processes (numbered for reference):

1. Concept Generation, Product Planning, Product Engineering, Process Engineering, Ramp-up of Production (Clark and Fujimoto, 1991):
2. Concept Development, Product Planning, Product and Process Engineering, Pilot Production and Ramp-up (Wheelwright and Clark, 1992)
3. Planning, Concept Development, System-level Design, Detail Design, Testing and Refinement, Ramp-up & Production (Ulrich and Eppinger, 1995)
4. Initial Screening, Preliminary Market Assessment, Preliminary Technical Assessment, Detailed Market Study, Business and Financial Analysis, Product Development, In-house Product Testing, Customer Product Testing, Trial Sells, Pre-commercialization Business Analysis, Production Ramp-up, Market Launch (Cooper, 2001)

While most processes (1, 2, 3) span the activities from understanding the customer needs, fundamentally verifying the business sense of developing a product, designing the product over various stages to production ramp up, one also includes the phase of market introduction (4).

Notably, the activity of technology management (Burgelman et al., 2008) is absent from all of these models, although it has been identified as an important element for the success of new product development projects (Song and Montoya-Weiss, 2001, GAO, 2010, Daim et al., 2009). Also, an overall project management function (PMI, 2004), as well as the management of PD project portfolios (Cooper et al., 2001) is absent, although these activities make important contributions to the "front end" of the PD process, which is vital for a successful PD project (Khurana and Rosenthal, 1998)

In order to integrate these missing elements with the already existing elements, the following generic PD process is proposed (see Figure 1).

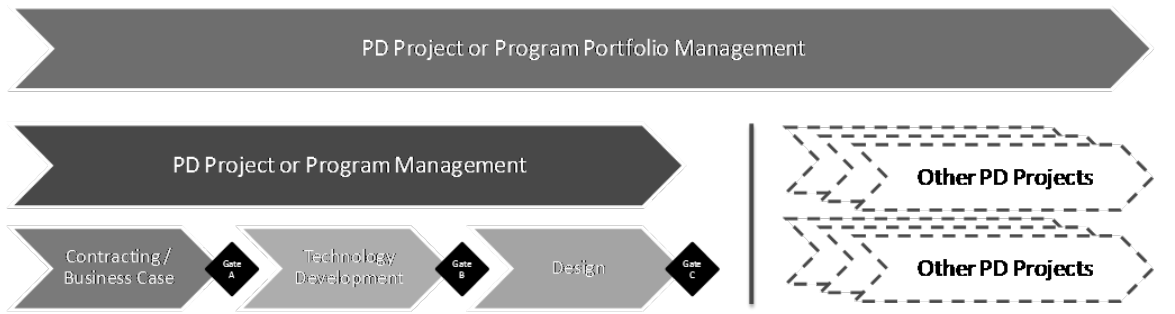

Figure1: Proposed Generic PD Process

It consists of the following five elements:

- The **PD project or program portfolio management** is responsible for managing the overall portfolio of all PD projects of a business unit or company. It falls within this phase to decide about the start of a project, resource (re-)allocation during project execution, as well as go/no-go decisions at stage gates.
- The **PD project or program management** activity is the overall coordination function in the PD project. It is the ongoing management function that integrates the activities in the three phases described below, as well as supports the integration of the project into an overall project portfolio management.
- The first phase in the PD project is the **contracting phase** with a customer (for an engineer-to-order product) or the **development of a business case** (for an internally funded development for a specific market rather than a single customer). The first phase ends with stage gate A, where the stakeholder requirements have been clearly defined and either a business case has been made or contractual agreements reached with the customer.
- The second phase is **technology development**, where the technologies are developed to reach the necessary level of maturity (if necessary). Technology

development ends with gate B, where all critical technologies have reached a sufficient level of maturity to allow the systems-level and detailed design of the product to go forward.

- The third phase finally is the **design phase** as such, where the systems design and detailed design are executed, and the various "Design for X" aspects (manufacturability, maintainability etc) are addressed. It ends with gate C, when a complete set of product specifications that address all production, operations and service needs have been created.

In regard to risk management, a number of risk management processes on different levels of abstraction that can be applied to various types of PD processes have been proposed. These include:

- General risk management processes, such as Orange Book in the UK (HM Treasury, 2004) or the Canadian Integrated Risk Management process (TBC, 2004)
- Project risk management guidelines, such as the risk management process of the PMBOK (PMI, 2004) or the Management of Risk process associated with the PRINCE2 project management framework (OGC, 2007)
- Risk management processes in software development, such as the risk management process from the Software Engineering Institute (Gallagher, 1999)
- Risk management processes for complex and technology-heavy products, such as the risk management standard of the US Department of Defense (DoD, 2006), the standard of NASA (Dezfuli et al., 2010), or the systems engineering risk management process (INCOSE, 2004)
- The first standard of risk management that claims universal applicability is the ISO 31000 standard "Risk Management – Principles and Guidelines" (ISO, 2009).

Comparing the various standards, the ISO 31000 provides the most promising candidate to serve as the basis for the development of a customized PD risk management process. It was explicitly developed to provide such a basis and it addresses the complete scope of risk management activities. Furthermore, it allows the integration of PD risk management processes with risk management processes in other functional areas (such as SCM) and other levels of the organization (such as enterprise risk management) and it understands and presents risk management as an integral part of decision making.

The proposed risk management process consists of the seven steps of 1. Communication and Consultation; 2. Establishing the Context; 3. Risk Identification; 4. Risk Analysis; 5. Risk Evaluation; 6. Risk Treatment; and 7. Monitoring and Review. These process steps are customized to the different elements of the generic PD process, especially regarding the use of specific methods to execute these steps. Also, the 1st, 2nd and 7th step are centrally executed in the project management element, whereas all other activities are each executed within every process element.

The comprehensive framework introduced above makes it possible to link decisions made at the different levels of the PD process to their supply chain risk implications. The following supply chain risk case studies were examined:

- Boeing 787 Dreamliner (Tang and Zimmerman, 2009)
- Sourcing from Low-Cost Countries (Oehmen, 2009)
- Department of Defense Development Programs (GAO, 2009, GAO, 2010)
- Textile and Apparel Industry (Khan et al., 2008)

Boeing decision to compete based on innovation is an example of a decision taken at the **portfolio/business level** that has many supply chain risk implication. This decision included involving suppliers who will design and build entire sections of the plane and the use of new composite material for the fuselage that has not been used before in this industry (Tang and Zimmerman, 2009). This exposed Boeing to some sort of dependency on suppliers to develop mature technologies. In the apparel industry, decisions reduce time to market to be responsive to fast changing markets exposed the industry to capacity problems (Khan et al., 2008). Standardization and commonality decisions are very attractive strategies for reducing the complexity of the supply chain, simplifying inventory management, reducing time to market, reducing supply demand mismatch but can lead to serious supply chain risks if only a single source is available (Oehmen, 2009).

At the **project management level**, examples include decisions to outsource product development of components and sub-assemblies to suppliers which may create risks of

dependence on these suppliers for developing mature technologies and providing know how. But in long run this limits the capacity of the firm to innovate as it loses that capacity over time to its suppliers. Certain cost and quality decisions at this level such that as using company position and power to dictate cost and stringent quality requirements may lead to the loss of important suppliers.

At the **contracting / business case level**, the use of profit risk-sharing contract may lead to misalignment of the incentives among key stakeholder as was the case with Boeing and its suppliers (Tang and Zimmerman, 2009). Lack of early customer integration can result in demand supply mismatch. Also inaccurate cost and schedule estimation can lead to many problems with suppliers such as misalignment of incentives that may lead to tremendous cost overruns and long delays (GAO, 2009, GAO, 2010).

The Boeing case (Tang and Zimmerman, 2009) also provides an illustration of the supply chain risk due to reliance on supplier for new **technology development**.

At the **design level**, supplier integration in early design stage, and the use of modular designs are proven methods for improving supply chain performance but also generate supply risks such as dependency on supplier, loss of the capacity to innovate, and dependence on single source of supply (Khan and Creazza, 2009).

These examples clearly illustrate the benefits of the proposed framework in terms of its ability to manage supply chain risk by carefully managing decisions taken at the early PD stages.

RESEARCH LIMITATIONS/IMPLICATIONS

The proposed conceptual framework for integrating supply chain risks in product development is based on existing PD, RM, and case studies related to these topics from the literature. It is the intention of the authors to refine this framework and validate it through research collaboration with industry. This is an extremely vital next step in our research to make sure that this framework is relevant and useful to practitioners.

PRACTICAL IMPACT AND CONCLUSIONS

Early on, most organizations have been functional in their structure with responsibility for each stage in the value chain, including design, being separate from the other. Design was the responsibility of technical people with minimal involvement from other function. The need for designing product that can be easily manufactured gave rise to the concept of design for manufacturing. Then came the need for design cross functional team involving most key function become the norm. As the physical characteristics of the product will influence logistics costs e.g. storage, handling and transportation, design for logistics was the next opportunity for improvement.

This evolution means that we must see design as much more than just an activity which creates novel ideas or brings stylistic changes to products. There is in fact a more strategic role for design which impacts the total supply chain (Abecassis, 2006, Ragatz et al., 1997). From this we can conclude that product design is a key determinant in supply chain success and that successful companies will be those which seek to extend and develop the contribution design into all aspects of their business

The proposed framework is meant to achieve this comprehensive view of PD and its implications. We believe that, once refined and validated, this framework will provide a consistent process for managing risk at all levels

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Section 3

Supply Chain Risk Management- A Sectoral View

SUPPLY CHAIN RISK: COMMONALITIES AND DIFFERENCES BETWEEN ITALY AND SWITZERLAND/GERMANY

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ABSTRACT

In this paper, we introduce a survey with companies from Italy and Switzerland/Germany. The survey questions address issues around supply chain risk, mitigation and management approaches as well as cultural aspects that play a role. We briefly discuss and compare some of the data of the survey results.

PURPOSE AND BACKGROUND

Supply chain trends continuously change the risks companies have to face day by day, from supply disruptions to demand upsurge and downturn. However, the approach to these different types of risk is generally not homogeneous moving from one country to another. As argued in Douglas and Wildavsky (1983) each form of social life has its own typical risk portfolio, and cultural differences and local habits might shape risk perceptions in different ways.

The purpose of this paper is to present some of the main results of a global survey about experiences and attitudes toward supply chain risks and risk management in companies based in different countries. The survey was set up by the MIT Center for Transportation & Logistics as part of the global scale risk survey at MIT (ctl.mit.edu/research/global_scale_risk_initiative). This initiative was aimed at understanding regional and cultural differences in the way that supply chain risk is perceived globally. For this purpose, the survey was conducted in different countries in Europe, North America, South America, Africa and Asia.

Both, the CELS – Research Center on Logistics and After-sales Service and the BWI Center for Industrial Management contributed to the survey managing dissemination and data collection activities in Italy and Switzerland/Germany, respectively. Thus, the questions were translated to Italian and German language and companies within the countries were contacted and asked to participate in the survey.

The main goal of this paper is to compare some of the data collected in these European countries, underlining the differences and commonalities in approaching supply chain risk management in the surveyed countries. Switzerland and Germany have been grouped together to represent one region here because of cultural and regional proximity. Also comparatively few Germans (less than 10%) were among the respondents.

RESEARCH APPROACH

The results presented in the remainder come from the above mentioned international survey. Due to the scope of the paper and the extent of the data, we only analyze the survey results partially. Moreover, due to some confidentiality agreements and restrictions on sharing data, the cross-analysis will be performed only considering aggregated data.

Survey questions were mainly based on Likert-like scales, while some open questions were included too. The raw survey data was cleaned for incomplete answers before processing and further analyzed by taking averages and counting percentages. The sample size for Italian companies was 74 and for Switzerland/Germany 141, providing a broad enough base to derive a general understanding and perception of supply chain risk.

FINDINGS AND ORIGINALITY

In this section we report some of the key findings of the comparison of the survey results. Figure 1 shows the aggregation of the answers given to the question whether mitigation efforts should focus on prevention or event response. The graph shows a strong tendency towards risk prevention (about 60% of both samples) as a preference, which is not surprising: risk taking especially with unclear outcomes is not part of either country's management culture and not encouraged through incentives. Nonetheless, about 25% of both samples consider prevention and reaction to be equally important, which could be interpreted as an undecided position where no clear management approach has been taken. Swiss/German survey respondents tend to answer less extreme than their Italian counterparts which aligns with common stereotypes. From the analysis emerges that from the respondents' view, the general focus of risk management should be on the preventive side.

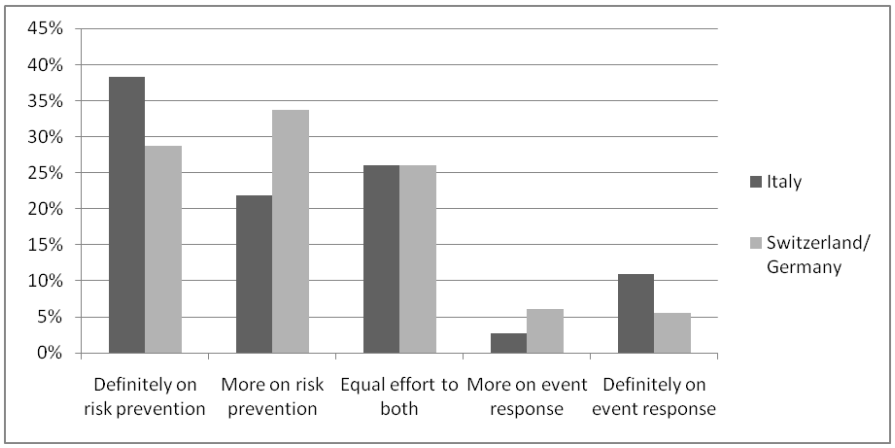

Figure 1: How companies spend their efforts in managing risks

The following graph depicts results about the best position in an organization to manage risks. The two extremes of the Likert-scale are the complete centralization on one side and complete decentralization on the other, with two intermediate levels in between. Considering the radar-like graphs in Figure 2, the closer to the center of the square the line is, the more centrally the activities should be performed. For example, in both countries the "Planning of risk prevention measure" should be performed in a decentralized manner, while "Performing event response" actions should be deployed more centrally.

The main implication of these results is twofold: first, Italy and Switzerland/Germany appear to have a similar attitude towards the centralization/decentralization dilemma; secondly, planning activities show a slight tendency to be favored as a central activity as opposed to implementation of response or prevention measures. This second observation seems to be aligned with expectations: assuming a centralized point of view can favor a broad perspective about risks, while actions should be taken locally wherever a disruption occurs.

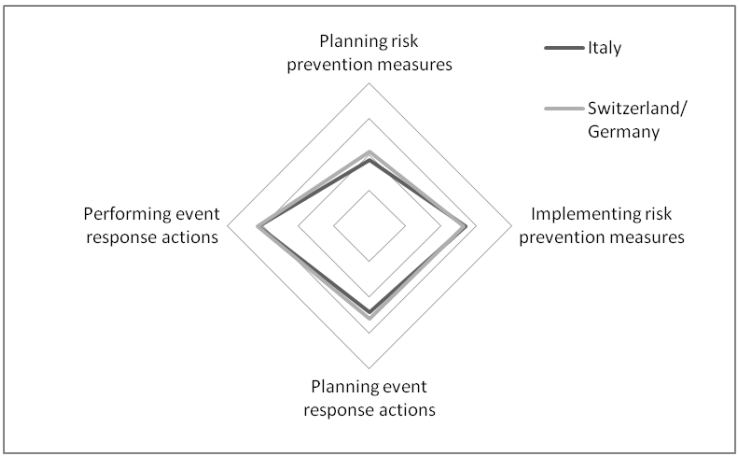

Figure 2: Where is the best position to plan or implement actions?

Figures 3 and 5 depict the frequency of different disruptions to the supply chain caused by either internal or external risk. They are derived from Likert-like scales which range from answer possibility 1="Never" up to 5="Almost Daily". The informational value of the results are of course limited due to the nature of the scale. Especially the comparison of results has to be executed carefully, as the perception of items is likely to vary between respondents. Nonetheless, we used average values to derive basic implications.

Product quality failure, transportation carrier failure, as well as inventory write-off, raw material cost and major software system failure are among the most common internal disruption causes. Generally, Italian companies are more affected by transportation carrier failure with respect to their Swiss/German counterpart. On the other hand, Swiss/German companies suffer more demand downturn and problems related to raw material suppliers and costs. Nonetheless, the differences are not so eminent.

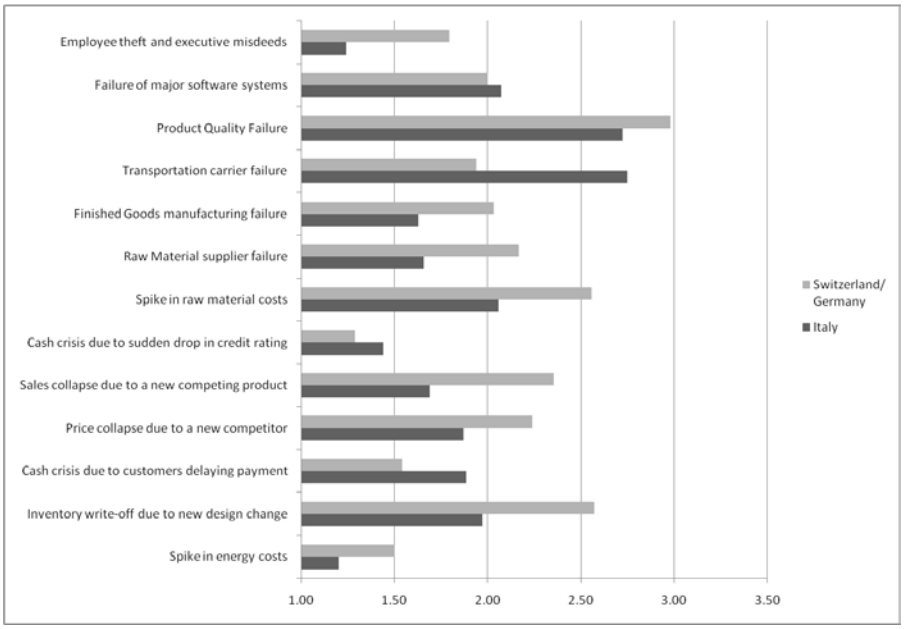

Figure 3: Frequency of supply chain disruption due to internal events

It is interesting to cross-analyze the frequency of occurrence of disruption due to internal events and the approach adopted to risk management, discussed in Figure 1. In Figure 4 the vertical axis measures the frequency of occurrence of the specific events reported on the horizontal axis; as depicted there, risk prevention and event response approaches almost always dominate the undecided approach of respondents who declared to put equal effort to both.

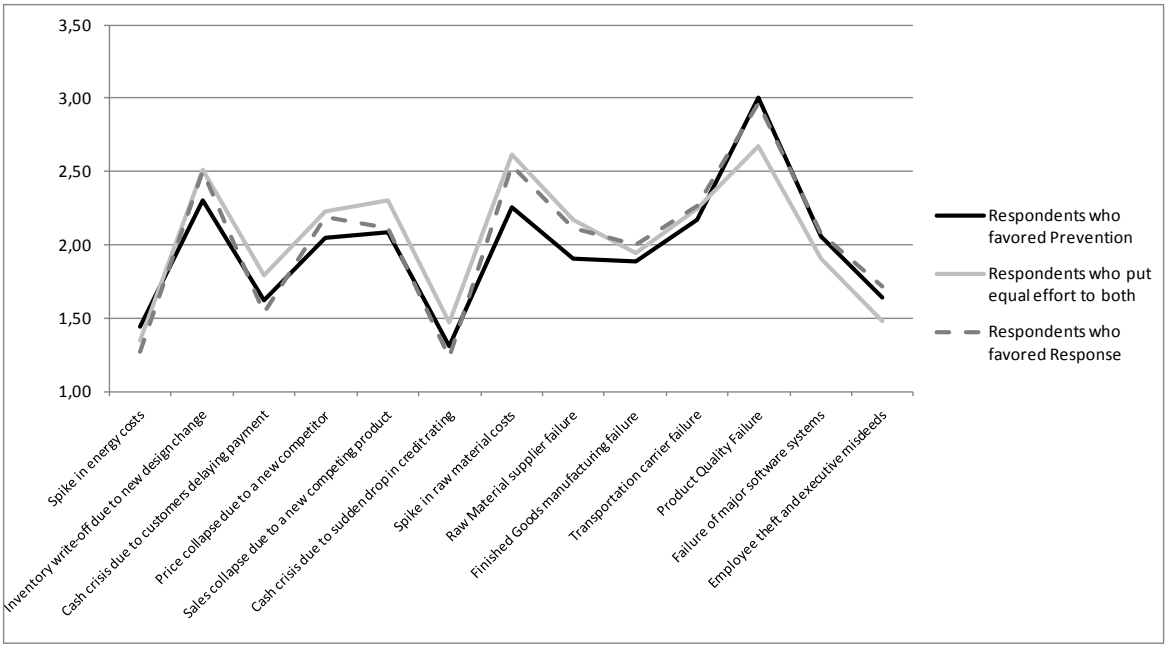

Figure 4: Comparison of disruption occurrence in companies adopting different risk management approaches

Considering external events, economic recession and currency risk – probably strongly influenced by the recent global economic turmoil –, product tampering, labor disputes and virus or cyber attacks are the most prominent reasons for disruptions.

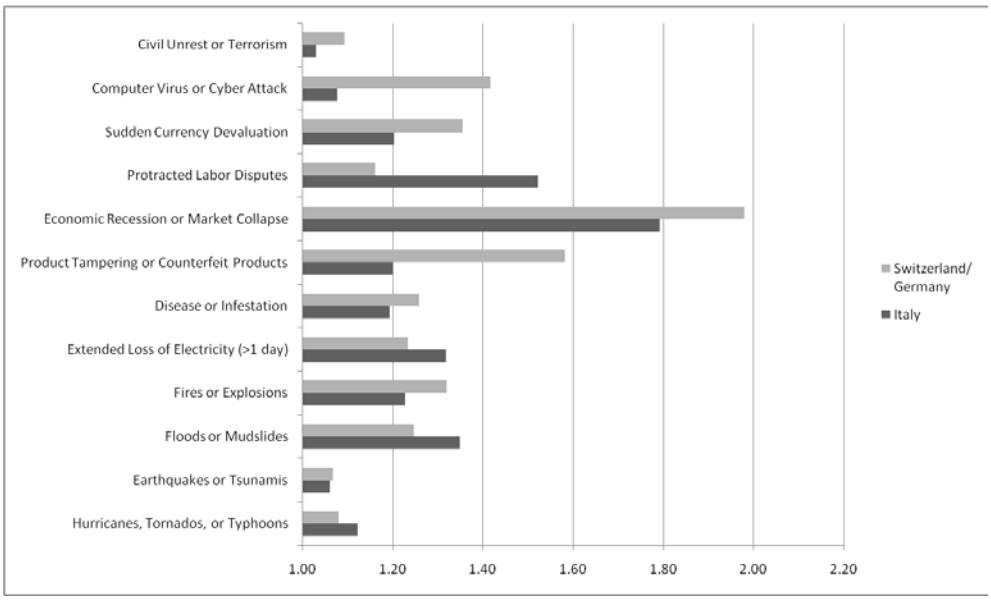

Figure 5: Frequency of supply chain disruption due to external events

Again, differences between the two countries are not immense. However, Swiss/German companies face product tampering more often than Italian ones, who have experienced protracted labor disputes more often than their Northern neighbor. This also reflects the different situations at the two labor markets and the strong focus on branding of Swiss/German companies with regard to quality.

Next, Figure 6 describes which types of risk management instruments, procedures or staff are implemented and employed. The answer possibilities included ”Yes and its is effective”, ”Yes but it is not very effective” and ”No”. This scale therefore represents answer possibilities in decreasing effectiveness of supply chain risk management. The data is aggregated for both regions, as only minor differences were detected. However, we see

that available risk management tools are for the majority not used effectively, considering that an ineffective or no use of the corresponding risk management method was claimed for almost all methods listed. This shows how much effort is still needed in spreading and implementing the available methods effectively as well as developing new and effective ones.

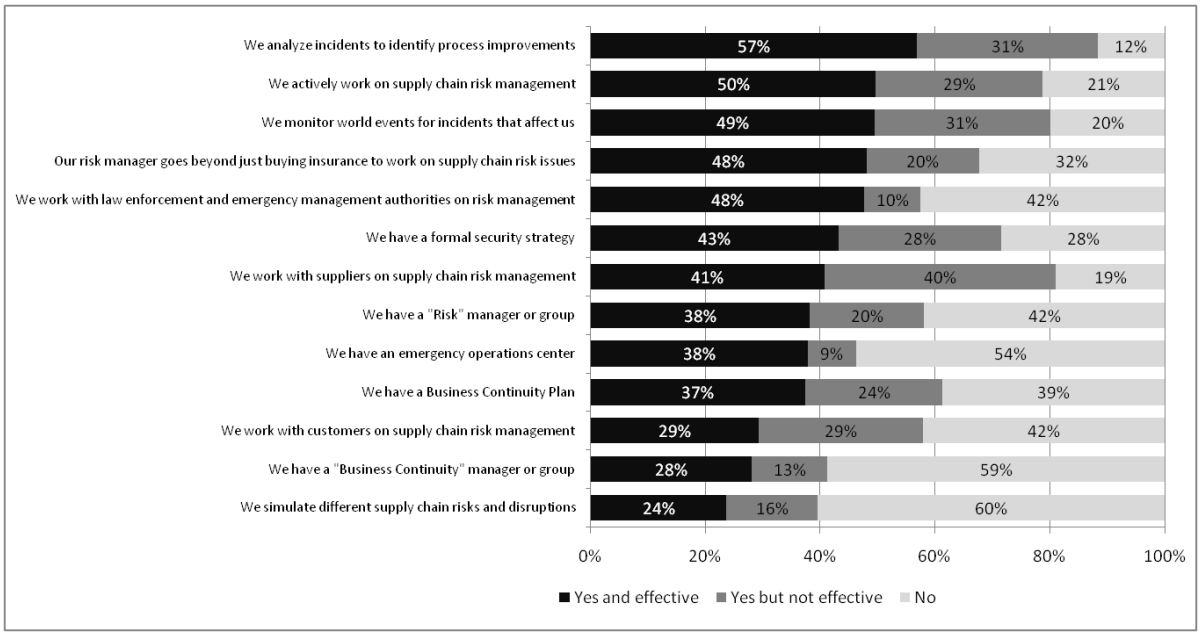

Figure 6: Supply Chain Risk Management approaches at surveyed companies

RESEARCH IMPACT

This research can provide an inside into how supply chain risk is managed and experienced by managers in different countries. The survey generally helps to identify where industry needs and research gaps are in terms of effective supply chain risk management approaches. However, more analysis including an analysis of the statistical significance of results should follow on the data available.

CONCLUSIONS

As also reported in Oltedal and Rundmo (2007) different worldviews did not lead to extremely different perception of risk in the two countries, and the relations between culture and risk perception seemed somewhat sporadic and unsystematic. Cultural and geographic proximities are an obvious explanation of the shown similarities.

Further analysis of the data with regard to for example the correlation of industries, individuals and surrounding culture with the answers provided in different questions could lead to meaningful results.

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SUPPLY CHAIN DISRUPTIONS IN SPARSE TRANSPORTATION NETWORKS – A NORWEGIAN PERSPECTIVE

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ABSTRACT

How are the supply chains of companies located in sparse transportation networks affected by transportation disruptions? What are typical disruptions in certain locations or for certain types of business, and how do businesses and carriers counter supply chain disruptions? A study commissioned by the Norwegian Public Roads Administration in 2008 investigated how companies located in sparse road networks are affected by and relate to supply chain disruptions.

PURPOSE AND RESEARCH APPROACH: INTRODUCTION

Transportation networks are the main backbone of modern society and play an important role in supply chains, especially in sparsely populated regions with sparse transportation networks. Typical traits of such regions are few transportation mode options and/or few transportation link options for each transportation mode, for example maybe only one railway line and two roads, no port, no airport. How are the supply chains of companies located in sparse transportation networks affected by transportation disruptions and how do freight carriers cope with these disruptions? The companies for the study (Husdal and Bråthen, 2010) were selected across industry sectors, presumed to be heavily reliant on road transportation, and presumed to be geographically challenged or so-called unfavorably located. Three transportation-dependent businesses and 14 freight carriers were in structured interviews asked to report on their experiences with transportation and supply chain disruptions, their consequences and costs, and which, if any, mitigative or contingent measures that were or are now in place to deal with disruptions. While this paper only summarizes the research and the findings, a more extensive presentation can be found in Husdal (2010).

LITERATURE REVIEW: THE IMPORTANCE OF ROADS IN SUPPLY CHAINS

The vulnerability of the road network, without focusing specifically on freight issues, has been the subject of academic research for some time (Dalziell and Nicholson, 2001; LLeras-Echeverri and Sanchez-Silva, 2001; Berdica, 2002; Cova and Conger, 2004; Di Gangi and Luongo, 2005; Laird, 2005; Husdal, 2005; Jenelius et al., 2006; Taylor et al., 2006). Parallel to this, in a separate research strand, the importance of transportation network for supply chains and freight distribution is also gaining momentum (Christopher et al., 2002; Svensson, 2002; McKinnon, 2005; Sanchez-Rodrigues et al., 2008; Heaslip et al., 2009; Husdal, 2009; Ta and Pitera, 2009; Sanchez-Rodrigues et al., 2010), thus indicating a distinct link between transportation disruptions and supply chain disruptions. Among the first practical guides to address transportation as part of supply chain risk management was Giertz (1999), a Swedish handbook very similar to the self-assessment workbook published by the UK Department of Transport (2003). Peck (2006) argues that supply chain management (SCM) often overlooks or neglects the mundane side of physical distribution and transportation, despite the fact that these activities form the backbone of SCM. The issue of supply chain disruptions is of particular importance in sparse transportation networks, because here the consequences of any uncertainty in the availability of the transportation network can be potentially severe. With only few transportation modes and/or links available between communities, these communities become extremely vulnerable to any disruption, since in a possible worst-case scenario no suitable alternative exists for deliveries to or from these communities. This makes supply chain disruptions in a sparse transportation networks different from disruptions a non-sparse network, since supply chains, here more than elsewhere, serve a purpose that extends beyond the immediate concerns of SCM.

IMPLICATION: A NEW FRAMEWORK FOR CATEGORIZING SUPPLY CHAINS

The notion of limited options in sparse transportation networks can be developed into a four-type classification scheme for supply chains, based on the number of transportation modes (road, rail, sea, air) and number of links available within modes: Free, Directed, Limited and Constrained, as shown in Figure 1. In a free supply chain there are little or no constraints as to transportation modes and there is a dense transportation network with many possible links. In a directed supply chain there are many possible links, but few modes, thus directing the supply chain towards a certain mode or set of modes. In a limited supply chain there are many mode choices but few links, which creates an overall limited setup. In a sparse transportation network neither modes nor links are a matter of choice, and the supply chain is effectively "locked" to the existing options, i.e. modes or links. In a constrained supply chain there are few choices as to mode and/or links and in worst case the supply chain is locked to one mode and very few, or maybe, only one link.

		MODES	
		Few	Many
LINKS	Dense	Directed Supply Chain	Free Supply Chain
	Sparse	Constrained Supply Chain	Limited Supply Chain

Figure 1 - Four categories of supply chains, based on transportation modes and links

Admittedly, this is a very crude classification scheme, since a "free" supply chain with all modes available, but with capacity constraints on all or some of the links and/or modes is no longer a true "free" supply chain. Capacity constraints, or cost constraints for that matter, are thus factors that would turn a seemingly free supply chain into one of the other types of supply chains.

IMPLICATION: A FRAMEWORK FOR ADDRESSING RISKS IN SUPPLY CHAINS

Combining Jüttner et al. (2003), Christopher et al. (2004), and Craighead et al. (2007), it is possible to construct the following argument: On one side a supply chain is exposed to certain risks, that depending on the risk drivers, may (or may not) lead to certain consequences, i.e. supply chain disruptions. On the other side, the supply chain has certain characteristics, which determine the severity of supply chain disruptions: a) supply chain design characteristics and b) supply chain mitigation capabilities. In other words: the impact of supply chains disruptions depends on a) the structure and b) the organization of the supply chain, where the structure makes up the "physical" side of the supply chain and the organization makes up the human side of the supply chain. These two parts are complementary in that both are needed for the successful handling of a supply chain disruption, while at the same time, a deficiency in one part can be compensated by the strength of the other part, i.e. a badly structured supply chain can be strengthened by a well organized supply chain. Within this framework, a company can address supply chain disruptions in two ways: 1) Redesign the supply chain towards a better structure, in order to gain a better location, or 2) Redesign the supply chain towards a better organization, in order to gain better preparedness.

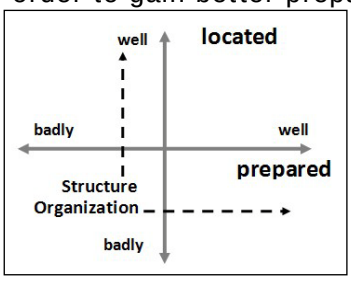

Figure 2 - Structure and organization influence preparedness and locational favourability

Following the view of Asbjørnslett (2008), both risk addressing strategies ought to be differentiated into mitigative strategies (reducing the exposure to risk sources and drivers)

and contingent strategies (reducing the impact of consequences). Because the supply chain structure is closely linked to the four types of supply chains mentioned earlier, in the case of constrained supply chains the structure can be seen as fixed, and consequently, the only point of attack for overcoming transportation disruptions is increased preparedness through improved organization, as shown in figure 2. The purpose of the aforementioned study was to verify if this was the case.

FINDINGS: TYPICAL SUPPLY CHAIN DISRUPTIONS

In sum, all carriers had experienced disruptions resulting in consequences for the sender and/or intended receiver of the goods transported. Below are some of the most frequently mentioned issues:

- Late arrival of perishable goods (fresh fish) to marketplace. Carrier had to reimburse the loss of value from selling a low-quality (not fresh) product.
- Truck driver stops in accordance with driver resting hours. Misses ferry, resulting in further delays en route.
- Road closure due to roadwork. Truck cannot reach manufacturing facility, which has to shut down temporarily.
- Ferry link safety issues. The regular vessel is taken out of service and safety regulations prohibit the substitute ferry from carrying too many trucks with hazardous goods or prohibit the ferry from carrying such goods at all, resulting in a long detour and further delays,
- Ferry link capacity issues. If there are several vessels serving one link, they are often not of uniform size, and some departures may thus have capacity constraints. While drivers may aim for a certain favorable departure, en route delays may hinder this, and the capacity constraint on the unfavorable departure poses another hindrance and further delays.
- Late arrival. An en route delay causes a truck to arrive at a freight terminal after hours. Crew must be called in for loading and unloading of goods. Carrier has to pay overtime for terminal workers.
- Wrong or incomplete documentation. Goods are often not picked up or delivered because driver/carrier/forwarder/terminal operator lacks full information on what is to be picked up or delivered where.

The interviews also showed that the carriers were acutely aware of their important role in the overall supply chain. Note here that while ferry links are perhaps a typical coastal Norwegian problem, and most likely not found to this degree in many other countries, it does show how all elements of the transportation network contribute to the overall performance of the supply chain.

FINDINGS: FREIGHT CARRIERS' MITIGATIVE AND CONTINGENT MEASURES

As earlier noted in the discussion on risk sharing, the carriers are the supply chain elements that experience the immediate effects of a transportation disruption, and thus they are also closest to finding measures than can reduce the probability or impact of disruptions. The answers as to what each carrier saw as typical measures varied widely, but some answers occurred more often, such as

- Contingency contracts with companies offering maintenance, repair, rescue or towing services along the most frequently used road links.
- Cooperation agreements with other carriers to secure replacement drivers or replacement vehicles for transferring goods from the broken vehicle to the replacement vehicle.
- Structural and/or technical modifications of vehicles and equipment to improve operations, particular under winter conditions.
- Regular dissemination of information to drivers where to find which roadside assistance..
- Neutral and non-descript packaging to avoid theft of valuable goods.

- Sufficient slack in lead time of scheduled routes in order to account for possible delays.
- Depending on the external circumstances, no guaranteed lead time or arrival time.

Particularly the two first answers were cited as the most important mitigative and contingent measures vis-à-vis transportation disruptions. The last measure, "no guarantees" was often used during winter, or when known road closures along the normal route meant that the truck had to use an alternate route.

RESEARCH IMPLICATION: FUTURE QUESTIONS

Our selected sample of transportation-dependent businesses and freight carriers has shed some light on how transportation disruptions affect supply chains, and ought to provide a fruitful starting point for further research opportunities. Figure 3 suggests the framework for such research. Question that could be asked are:

- Which risk sources can cause transportation disruptions in ingoing or outgoing flows, related to supply and demand and flows internal to the company, and what are the consequences related to supplier, customer and the company itself?
- What risks lead to which consequences and how are they handled or mitigated?
- How do different manufacturing processes (make to stock, make to order, engineer to order) reflect on the risks and consequences?

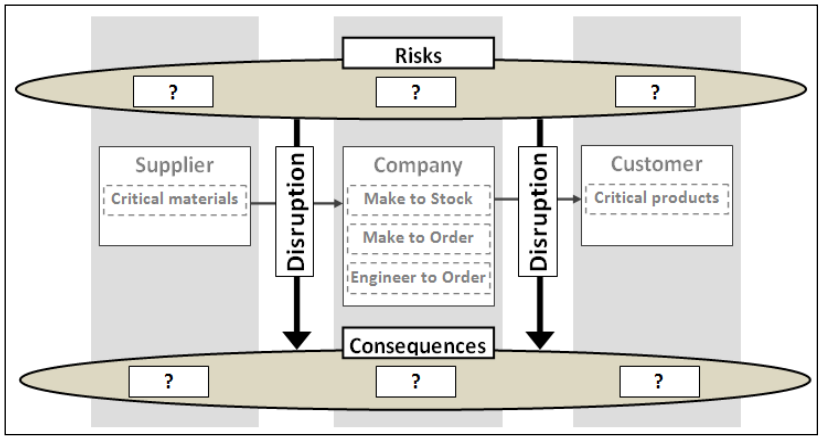

Figure 3 – Framework for future research

PRACTICAL IMPACT: RISK SHARING

Transporting goods from one place to the other will always have a risk of the goods not arriving on time or in broken condition, and a transportation company (i.e. freight carrier) that accepts a transportation order from a freight forwarder or directly from a freight owner will want to clearly identify and contractually determine which party that is bearing which risk. The study indicates that transportation-dependent businesses seek a vertical integration of a freight carrier into their supply chain, while freight carriers establish asset-specific and flexible solutions to meet the contingent needs of different businesses. In practice, this means that the carrier bears risks associated with equipment, vehicles or infrastructure-related events, while the freight owner (sender or receiver) handles risks associated with overall project delivery or risk related to the suppliers or end users of the goods transported.

CONCLUSIONS:

With transportation networks being an integral part of supply chains, transportation disruptions are in turn an integral part of supply chain disruptions. Preparing for disruptions should therefore be an integral part of supply chain risk management. The framework suggested here will hopefully contribute to that.

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DRIVERS OF SECURITY IN DISTRIBUTION NETWORKS – A SURVEY OF SWEDISH TRANSPORTATION COMPANIES

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PURPOSE:

Available statistics report the existence of several criminal activities affecting global supply chains. These incidents are not often publicly reported by firms because of the negative effects they may have on the brand image of the organizations involved (Ekwall, 2007). However, the magnitude of their frequency as well as of the related consequences are so incredibly high that many supply chain firms have indicated "*security*" as one of their management top priorities to work on within the next years (Thomas, 2006).

Today security, logistics and supply chain managers have wide access to handbooks, certification programs, advanced security technologies etc., to enhance the protection of their assets. Technology is at the forefront and offer wide sets of solutions to hinder criminals from attacking cargo (Sheffi, 2001). In addition, often organizations have specialized security personnel that is in charge for spreading the security culture among the employees as well as to ensure that security routines and technologies are correctly implemented and working in line with the organizations' operations (Willys and Ortiz, 2004; Peleg-Gillai et al., 2006; Rice and Spayd, 2005; Lee and Whang, 2005). Business security certifications as the ISO28001 or TAPA EMEA's are available to practitioners to support the understanding of security and learn how to prevent antagonistic threats. Likewise, the authorities around the world are developing security certifications to enhance the protection of global distribution networks, i.e. C-TPAT, AEO, ISPS etc. (Sheffi, 2001; Rice and Spayd, 2005) Despite this, statistics tell that there are huge vulnerabilities in distribution networks turning them into low-risk/high-revenues targets. Every day cargo is stolen, hijacked, counterfeited as well as personnel working in transportation companies is exposed to the risk for being seriously injured. Less often, we witness episodes of terror attacks or food and pharmaceuticals contamination that have terrific consequences on our communities. Hence, we wonder how supply chain, transportation and distribution companies are coping with this situation that we don't believe is sustainable neither from an economical nor from a social responsibility viewpoint. Hence, the purpose of this paper is to discover and demonstrate what factors are determining the insecurity of distribution networks.

RESEARCH APPROACH:

The methodology followed in this research is mainly based on an explorative study followed by a survey. Thus, the whole investigation is based upon a combination of qualitative and quantitative methods which is a recommended approach within logistics research (Dunn et al. 1994; Näslund, 2002; Mangan et al., 2004). Methodological triangulation, that is the usage of different research approaches, techniques and methods in the same study, may help investigators to overcome the biases and deficiencies of single method approaches (Easterby-Smith et al., 1991; Denzin, 1970; Mentzer and Flint, 1997). The explorative study is meant to be based on the grounded theory approach that is a proper method to generate theory from empirical observations (Strauss and Corbin, 1990). A literature search, 4 qualitative unstructured and 12 semi-structured interviews as well as observations performed in occasion of two security workshops were exploited to gather data concerning the factors influencing the efforts made by transportation companies to enhance security. The qualitative interviews were discontinued as soon as data saturation occurred. In addition, further interviews were performed later to ensure the stability of the data over time (Glaser and Strauss, 1967; Easterby-Smith et al., 1991). Themes, patterns and categories were identified by means of comparative processes. The results from this explorative study are formulated in form of 19 hypotheses. Thereafter, a survey was conducted to test the hypotheses formulated in this paper. More specifically, multivariate techniques are used to test the hypotheses. First of

all, whenever more than one variable was used to measure the predicting factors formulated in the hypotheses 1) a factor analysis was run to discover underlying dimensions in the variables and 2) a reliability analysis was exploited to determine the internal consistency of the factors discovered. To determine whether the collected data contained distinct and homogeneous groups of respondents with different profiles in relation to the factors determined above, a cluster analysis was also conducted. Three different cluster analyses were run by using each of the three factor components in combination with the size of the company. The cluster analyses were run with the Ward's method with squared Euclidean distance and standardized Z-scores. The identification of the numbers of clusters was performed by searching for sudden jumps in the distance coefficients. This was accomplished by plotting the agglomeration schedule coefficients against the numbers of clusters as well as by examining the dendogram. To identify the characteristics of the clustered groups, discriminant analyses with a Wilks' lambda stepwise method and a Varimax rotation have been computed. Thereafter a MANOVA was run to determine whether there was a significant influence on the discriminated groups on the security of transportation firms measured in terms of security investment and amount of security incidents borne (Hair et al., 2009).

FINDINGS AND ORIGINALITY:

At the end of this study, of the 19 hypotheses formulated, four are rejected and 15 are considered to be tenable. The Physical Distribution Security System is illustrated in Figure 1, where each actor is depicted with a roman number and the arrows show the interdependency among the actors and the physical distribution security. Summing up, the initiatives organized by the first actor (Actor I in the figure), the law enforcement agency, may positively stimulate the development and implementation of cooperative solutions to increase security. This can be done by 1) efficiently prosecuting criminals, 2) allocating more resources to fight cargo crime, and 3) organizing collaboration activities among cargo operators to strengthen security knowledge as well as application of routines and technologies.

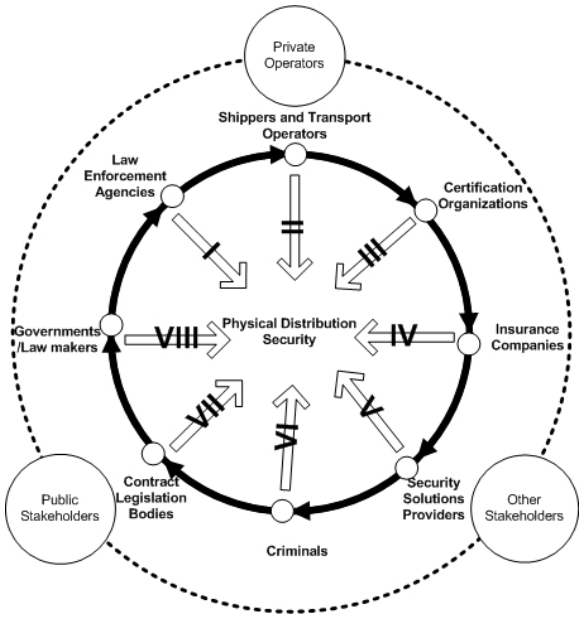

Figure 1. The Physical Distribution Security System (PDSS).

The second actor (Actor II, supply chain, logistics and transport operators), experience difficulties in defining security partnerships. Existing standard legislative commitments are too complex and at the same time don't support the definition of security requirements. In addition, this study confirms that the willingness to pay for secured freight transportation is still too low and the low marginal revenues that are typical of the transportation market make it difficult to afford security investments.

The certification organizations (Actor III, i.e. TAPA EMEA or ISO28000) represent an incentive for distributors to raise their security level and gain access to a network of secure operators. Hence, in this study it was hypothesized that standards, recommendations, and best practices can support shippers and transport operators in securing their assets and operations. Unfortunately, after clustering the respondents according to their compliance to security certificatios, no significant influence was found on the magnitude of security investments and amount of security incidents suffered. Hence, this hypothesis was rejected. The insurance companies, (Actor IV), seem to have both a negative and positive effect on the security of physical distribution. The negative impact is that it may happen that risk-seeking companies may trade-off insurance premiums and excesses with the implementation of security solutions. Nevertheless, insurance companies may stimulate the enhancement of security by offering premium discount to distribution operators.

The providers of security solutions are also encountering difficulties (Actor V). This work demonstrates that the absence of operational standards and advanced security products, makes the most of the security solutions as not mature to be fully implemented in physical distribution.

The behavior of criminals may also discourage the enhancement of security (Actor VI). As long as there will be weak links or nodes in a distribution chain, attacks will not decrease but will only move from the protected spots.

Contract legislation bodies (Actor VII) are today used to define transport assignments as well as cargo liabilities among all the involved stakeholders. However, these don't provide any support to agree on security requirements to be adopted. At the same time, it is not possible to verify that physical carriers follow what is stated in the contract.
Finally, governments have also a significant role in the enhancement of security in physical distribution (Actor VIII). Many believe that regulations may stimulate operators; however there is still confusion and uncertainty about the costs and related requirements of the authority certifications. Thus many companies are waiting.

RESEARCH IMPACT

Previous work appears to focus on conceptual normative approaches. Diverse articles emphasize the importance to perform more descriptive research in the area of supply chain security. Despite this, yet too little research has been driven to identify what factors influence the insecurity of distribution networks. Hence, this study has the ambition to unveil diverse factors influencing security of transportation companies that seem to be still unknown to the academic field. In addition, a survey study is performed demonstrate the validity of the hypotheses formulated as well as to fill the gap between normative and descriptive research conducted in the field.

PRACTICAL IMPACT

The practical implication of this investigation is to use the framework in
Figure **3** to stimulate stakeholders to identify initiatives that could bring mutual benefits and higher security to all the actors identified in the PDSS. The main recommendation is to accomplish this objective by promoting collaboration opportunities that may introduce new driving forces, remove the existing barriers or perhaps turn the barriers into driving forces. From the perspective of the authority, by verifying the existence and effect of intra- and inter-organizational factors influencing the security degree of distribution organizations, it will become easier to identify policies, programs or economical stimulation for companies required to enhance security. It is well known that the authority certifications as C-TPAT and AEO have encountered strong opposition and skepticism among stakeholders. Even though these certifications may become mandatory in the future, the truly commitment to security of organizations may be questioned because it may happen that many firms will only see these certifications as a means to avoid transport delays at customs or to gain competitive advantage on the market. Therefore it

is essential that distribution and supply chain operators are correctly stimulated to enhance security. From the viewpoint of logistics, supply chain and transportation stakeholders the understanding of what factors influence their efforts in security may make easier to initiate security initiatives, collaboration with security experts, as well as with private and public organizations and thereafter identify allocation of money and resources to improve security

CONCLUSIONS:

In conclusion, this investigation put forward a total of 19 hypotheses that unveil a complex system in which business mechanisms among eight actors may influence the insecurity of distribution networks. Such insecurity may determine huge losses for goods owners and transport operators but may also put into danger our communities (i.e. terror attacks, contamination and counterfeiting of food or pharmaceuticals). By performing a survey of Swedish transport operators, this investigation demonstrates that 15 of the 19 hypotheses formulated may be considered tenable.

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THE IMPACT OF SUPPLY CHAIN RISK ON REGIONAL ECONOMIES

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ABSTRACT
There is a powerful tendency to view supply chain risk from the perspective of dyadic relationships between buyers and suppliers. While this view has led to important insights about the extent and management of supply chain risk, it does little to illuminate the nature, extent, impact and management of larger-scale phenomena that negatively impact supply chain performance and ultimately business success. This paper examines the intersection of geography and economics as a way to provide a framework for understanding supply chain risk that extends beyond the dyadic relationship and underscores the importance of coming to grips with such risk in order to bolster business performance. Further, this paper represents an initial attempt to portray the impact of supply chain risk at a level that makes the impact on regional economies clear and serves to encourage broad collaboration, including public-private partnerships to mediate the sources of large-scale supply chain risk.

INTRODUCTION

Reviewing the extant literature in supply chain risk management (SCRM) points toward a focus on disruptive events that may be visited upon a firm as the result of its dependence upon another firm for important inputs. The focus tends to also be biased toward events that can be isolated within a given supplier, and thus are independent between firms. In this way, authors have focused on a realm of supply chain risk in which effective approaches can readily be devised to improve individual dyadic relationships or reduce dependence on particular instances of such relationships to risk exposure. However, the current literature is restricted in the extent to which it addresses complex business dynamics. Thus, the field of SCRM currently provides effective guidance for supply management professionals for a constrained set of circumstances for which solutions are more readily available while generally not addressing important aspects of contemporary business realities.

Among critical lapses in current SCRM coverage are situations in which elements of risk are not limited to a particular dyadic relationship (i.e., independent risk), but are instead rooted in general phenomena (i.e., common or shared risk). While strategists have long advised consideration of many such risks in the context of organizational strategic planning (e.g.; risk driven by the industry within which the firm operates; and risk driven by the societal environment; such as economic, technological, political/legal and socio-cultural forces; often associated with determination of opportunities and threats; see for example Friend and Zehle, 2009), the influence has not been extensive in SCRM. Addressing this gap in the current focus of SCRM not only could provide better and more extensive guidance for practitioners; it could also serve to clarify the strategic nature of SCRM.

Another critical lapse in current SCRM is that the focus on the dyadic relationship tends to center on relationships with the suppliers while paying far less attention to the nature of the linkages between firms along which value flows. This gap is similar in nature to the lack of attention to common or shared risk. In both cases, much of the risk may be beyond the control of the individual firm, and effective strategies for reducing the level of risk are difficult to conceive and implement.

To deal with the gaps in SCRM enumerated above will require attending to the impact of geography. Where a business is located impacts the type and level of supply chain risk it experiences. As I will describe below, in the aggregate, the impact of location on business exposure to supply chain risk is an important feature of the vitality of the regional economy. Successfully addressing these concerns will require collaborative efforts

between business interests and public policy makers (Smith, 2010a). As scholars, we can play an important role in informing and motivating the parties required for such collaboration toward effective efforts.

SUPPLY CHAIN RISK AND REGIONAL ECONOMIES

Cluster-based models dominate current policies geared toward regional economic development. Such models generally focus on interacting elements within the region and the extent to which location-based advantages, particularly in innovation of new products, provide an adequate engine to spur trade. Fundamentally, exchange with other regions provides the foundation for developing economic vitality that delivers improved standards of living by leveraging resources beyond those immediately available within a given location.

It is hardly surprising that trade should represent the way to a better life. Indeed, such exchange served to improve the lot of aboriginal peoples, as, for example, the potlatch conducted by American Indians on the Pacific Coast of the United States served to smooth out the vicissitudes of natural cycles in resource availability (e.g., harvests of wildlife that varied on a seasonal basis) associated with regions inhabited by individual tribes. Trade routes that moved resources between tribes up and down the West Coast served to provide a more consistent and better life style to these early inhabitants (Trosper, 2002). More recently, the emergence of the Scottish into the modern world can be seen as having resulted from circumstances that allowed their participation in trans-oceanic trade routes, a point readily grasped by Adam Smith and portrayed in his "An Inquiry into the Nature and Causes of the Wealth of Nations" (Herman, 2001). In recent times, the emphasis of economic developers driven by cluster-based approaches has evolved toward viewing economic vitality as the result of networks of related and supporting enterprises adding value (a "collaborative advantage," qqv, Information Design Associates, 1997) to exchanges with enterprises and individuals both inside and outside the region. While there has been a great deal of focus on the role of customer spending in driving the economy, the merit of considerations of ripple, or multiplier, effects in the economy derive from the importance of business-to-business exchanges (e.g., see Industry-by-Industry Total Requirements Tables produced by the Bureau of Economic Analysis of the U.S. Department of Commerce, http://www.bea.gov/industry/iotables/table_list.cfm).

It is worth noting at this point that the realities of these business-to-business exchanges can be observed in cost structures of individual businesses. Manufacturing firms tend to have a relatively high multiplier (about $2.49 in total requirements per $1.00 of business activity, according to the latest Bureau of Economic Analysis tables, see citation above), and it is quite typical that approximately 60-80% of the cost of goods sold (COGS) is for inputs purchased from other businesses. For services, across a number of service industries, the multipliers are substantially less than $2.00 per $1.00 of business activity, and it is typical that 60-80% of the cost of products sold (COPS) is for direct labor. Fundamentally, regional economies are advantaged by the exchanges between businesses, and thus, supply chain management is critical to gaining advantages from trade in recent times (Note the growing focus that Porter places on presence of capable, locally based suppliers; cf, Porter, 1990 and Porter, 2000).

If supply chain management is a source of advantage, then problems arising within the supply chain represent a negative force, impeding, slowing, and perhaps even stalling or eroding the impact of efforts at developing regional economies. Thus, SCRM is a critical, albeit underappreciated concern in promoting healthy regional economies. While supply chain inputs represent value to businesses, unmitigated supply chain risk represents a cost that detracts from the value that a business can produce and negatively impacts company performance. To the extent that location impacts supply chain risk, there are regional components to such risk, and the cost of this risk should be accounted for in attempts at understanding and improving business conditions.

EXAMPLES OF SUPPLY CHAIN RISK WITH REGIONAL ECONOMIC IMPACT

Two major spheres of supply chain risk with geographical connections derive from economic conditions and conditions rooted within the transportation networks that link suppliers to buyers. In the case of economic conditions, while the global economy has recently been tumultuous, the impact varied depending upon national and regional exposure. These variations mean that depending upon business locations, the experience of a given business could be considerably different. In many regions, the recession in the United States served to continue and exacerbate long-standing restructuring in the economy, with the resulting erosion of the industrial base. For some regions, the shifts were relatively modest, and for others, often in rural areas, the shifts were more momentous. Businesses in some regions experience more supply risk as a result of economic trends than do businesses in other areas, and the aggregate result of such risk impacts the regional economy.

Industrial decline as a source of supply risk can result from decline in local industries of importance, and can impact the viability of businesses not otherwise subject to economic pressures. For example, if a successful business is part of an industry that has seen decline, the business may not be able to adequately provide a market for critical suppliers. As part of a constricted market for these critical suppliers, this otherwise successful business may be challenged to source strategically imperative commodities so as to be able to execute its competitive strategy to preserve business performance (Smith 2010b).

Another way that industrial decline contributes to supply chain risk occurs when a business is dependent upon a supplier that is part of an industry in decline. As the supply base constricts, the buying business faces risk associated with limited alternatives and reduced leverage, once again endangering the ability to execute competitive strategy (Smith, 2010b).

Note that in both cases, the individual businesses may have relatively little ability to manage the supply chain risk, but it may be possible to collaborate toward a geographic strategy that helps to preserve economic vitality in the region. Such strategies may include partnerships for leveraging intellectual capital (e.g., partnerships with colleges and universities in the area), utilization of community resources (such as community craft and interest groups to develop new potential suppliers) and engaging policy makers to effect changes in the business climate.

The impact of geography on transportation has long been understood, and attempts at amelioration have generally focused on investments in new and better infrastructure. The importance of these efforts is well represented in a recent report of the World Economic Forum in which the state of infrastructure was utilized as a major component of the ranking of global competitiveness among nations (WEF, 2009). However, for many developed nations, investments in infrastructure have not kept pace with needs. In the United States, deteriorating infrastructure coupled with increasing demand and capacity constraints have served to dramatically amplify the level of uncertainty businesses experience in terms of transportation performance, increasing supply chain risk and resulting in increased business costs (e.g., Buddress and Smith, 2010). Further, increases in fuel prices increase uncertainty about the shipping costs associated with supply management, and these costs are disproportionately born by businesses in rural areas where long distances and lack of modal alternatives to trucks often rule.

As these examples show, not all geographic areas are equivalently impacted by factors that result in supply chain risk, and therefore, some regions are provided with comparative advantage as a result of location, and others are relatively disadvantaged. Further, in many cases the relative positioning is outside the control of businesses (and this is particularly true of the relatively small businesses that are increasingly the mainstay of the economies in many geographic regions), but they certainly impact business success and the economic vitality of clusters of businesses within the area surrounding a given business.

PRACTICAL IMPACT AND CONCLUSIONS

The examples provided above do not suggest all of the potential sources of risk that are related to location, but instead serve to illustrate the value of a location-based framework for seeking understanding of large-scale sources of supply chain risk that are difficult to identify and manage. Additionally, such a framework highlights the advantages to better managing such risks, and such advantages if identified as regional economic impact potentially could serve to spur and motivate collaborative efforts to ameliorate the risk to which businesses are exposed.

For example, in studies conducted to determine the economic impact of investments to improve transportation infrastructure, careful attention should be paid not only to direct impacts such as the value of materials moved and businesses attracted by such investments, but also to the value of cost savings that accrue as the result of reducing supply chain risk for current businesses. Indeed, such advantages may be the key to maintaining viability of key businesses, and may even free up resources to allow the best businesses to grow. The impact in this case could be not only to sustain current economic performance within a region, a valuable commodity in times of economic strife, but also to promote economic development and an improved economic environment. Given recent failures in attempts to attract and keep businesses in recruitment programs, such an alternative should be welcomed by the economic development community.

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EXCHANGE RATE RISK IN THE FASHION ACCESSORY SECTOR: A CASE STUDY

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ABSTRACT

This paper is based on ongoing research at Johnstons of Elgin, in conjunction with the University of Manchester. Johnstons of Elgin is a vertically integrated textile manufacturer in Scotland which produces fine cashmere and woollen goods for the luxury fashion segment. Through the research conducted to date, exchange rate fluctuations have been identified as a source of supply chain risk for Johnstons. Product design considerations have been identified as a main source of potential mitigation strategies to reduce exchange rate risk.

PURPOSE

With the strength of the pound decreasing in relation to the dollar over the past two years, Johnstons has become exposed to significant exchange rate risk. Therefore, the purpose of this research is to conduct a brief literature review, synthesised with company-specific data analysis, with an aim to identify appropriate actions that can be taken by Johnstons to mitigate supply chain risk associated with exchange rate fluctuations.

LITERATURE REVIEW

Tang (2005) states that relatively little literature exists that specifically addresses the issue of exchange rate uncertainty in supply chain network design. Compared to literally hundreds of articles published regarding demand uncertainty in supply chains, Meixell and Gargeya (2005) identified a more modest 18 supply chain models that have been developed which account for an exchange rate variable. The Tang (2005) and Meixell and Gargeya (2005) articles were chosen as a starting point for this research as they are both wide-ranging literature reviews of existing work related to supply chain risk, and each contains considerable content relating to exchange rate risk.

Perhaps the most cited tool for mitigating exchange rate risk is financial hedging. Financial hedging can be used in the short term to reduce the variability in a company's cash flows (Kazaz et al, 2005). Other common themes from the literature include operational cost reduction efforts as a means to reduce currency exposure (Schmidt and Wilhelm, 2000), and maintaining flexibility in manufacturing location and country of sourcing as keys to mitigating exchange rate risk (Huchzermeier and Cohen, 2006; Chopra and Sodhi, 2004). However, Nembhard et al (2005) caution that the value of operational flexibility as a strategy to mitigate exchange rate risk is often overstated due to the time lag required to implement changes in operations.

Product design considerations are cited as a potential source of exchange rate mitigation. Elmaraghy and Mahmoudi (2008) and Schmidt and Wilhelm (2000) both call for product modularisation and postponement as a means to mitigate currency risk. Designing products with alternative raw material inputs or components, and designing products with an aim to market them in alternative geographical regions are both cited as currency risk reduction tools (Tang, 2005; Chopra and Sodhi, 2004).

APPLICATION OF LITERATURE REVIEW TO JOHNSTONS

Johnstons is already engaged in the common practices of financial hedging and ongoing operational improvement efforts (such as warehouse cost reduction programmes). Additionally, Johnstons, as a single country producer with most raw materials sourced from one country (China), is not in a position to easily exploit the exchange rate

mitigation strategies of flexible manufacturing across various countries, or diversify its buying risks by sourcing from many countries.

Therefore, the literature, along with feedback from interviews with company directors, points to product design considerations as the next likely focus for mitigating exchange rate risk at Johnstons.

RESEARCH APPROACH

This research has been conducted using three methods: literature review, semi-structured interviews with company directors at Johnstons, and data collection and analysis regarding commodity pricing and internal standard cost fluctuations over the past three years.

FINDINGS AND ORIGINALITY

Johnstons' primary exposure to exchange rate risk can be communicated in Table 1. Cashmere is a dollar-based commodity, and most of the world's cashmere fibre is sourced from China.

	2008	2010
Cashmere Fibre	$100/kg	$120/kg
Exchange Rate ($/£)	2.00	1.45
Cost to Johnstons	£50.00/kg	£82.76/kg

Table 1: Johnstons cashmere standard pricing 2008 vs. 2010

Table 1 depicts the difference in cashmere raw material prices in 2008 and 2010. A 20% increase in cashmere fibre pricing has been transformed into a 65% total increase in standard input cost for Johnstons due to the depreciation of the pound against the dollar. Because of prudent financial hedging practices, Johnstons is not exposed to the full price increase in Table 1 – at least in the short term. Even so, the company cannot simply pass on the remaining cost increase to the customer. The increased input cost has the potential to limit sales, profit, as well as increase inventory and working capital. Other mitigation strategies must be considered.

From the literature, a summary of commonly cited exchange rate mitigation strategies has been developed (Table 3). The summary includes an assessment of the applicability of each strategy for Johnstons. The assessment is influenced by interviews conducted with Johnstons divisional directors.

Potential Currency Risk Mitigation Strategy	Source Examples	Practicality for Johnstons
Financial hedging on currency and commodities	Chopra and Sodhi (2004) Huchzermeier and Cohen (1996) Simchi-Levi et al (2008)	Yes - already in place
Global manufacturing flexibility	Chopra and Sodhi (2004), Huchzermeier and Cohen (1996)	Difficult, as Johnstons is currenly a single country manufacturer with no immediate plans of manufacturing outside of Scotland
Operational Cost Improvements	Schmidt and Wilhelm (2000)	Yes - ongoing
Diversify currency risk by sourcing from multiple countries	Huchzermeier and Cohen (1996)	Difficult, as most cashmere comes from China, and is bought in dollars
Reduce lead time for short life span products	Tang (2005)	Yes, focus on improved communication between customers, design staff and production staff during market sampling periods
Product design considerations - product composition	Tang (2005) Huchzermeier and Cohen (1996)	Yes, focus on developing less costly fibre blends
Product design - modularity and postponement	Elmaraghy and Mahmoudi (2008) Schmidt and Wilhelm (2000)	Difficult, as the product does not lend itself to modular manufacture. However, new technology such as digital printing could provide benefits of postponement
Product design considerations - alternate target market	Kazaz et al (2005) Tang (2005) Nembhard et al (2005)	Yes, focus on designs for consumer markets outside of the UK which are currently experiencing relatively high buying power against the pound

Table 2: Exchange Rate Risk Mitigation Strategies and Practicality for Johnstons

From the list above, three practical applications of exchange rate risk mitigation strategies are proposed for Johnstons. Each is directly related to product design.

- The use of alternate fibre mixes, such as extra-fine merino/cashmere yarn blends can be increased to design new products with a lower input cost than pure cashmere products.
- Products can be designed and marketed specifically to regions of the world where Johnstons products are currently more price-attractive than in the recent past due to exchange rate fluctuations. For example, the product design department can focus on meeting the tastes of consumers in the United States, who currently enjoy a stronger dollar compared to 24 months ago.
- Johnstons can gain the benefits of postponement by exploring such technologies as digital printing. Rather than dyeing yarn, then weaving it into a finished product, digital printing would allow Johnstons to weave a “blank” fabric, and then print on it after weaving. Benefits of this process include reduced finished goods inventory, and increased agility to meet customer demand in terms of both improved speed and variety. All of these could have the impact of reducing exchange rate risk.

RESEARCH IMPACT

The collaborative research project between Johnstons and the University of Manchester is of a two-year duration and currently in the early stages. In the next stage of the project the model proposed will be implemented and validated within the context of Johnston's supply chain for supply chain risk mitigation

Additional research will be conducted during the next two years. As the project matures and yields more data on the relative success of particular currency risk mitigation strategies, the research should take on significance beyond Johnstons and serve to inform the larger community fashion textile producers.

PRACTICAL IMPACT

This paper can be used immediately by Johnstons of Elgin as a practical guide for further risk mitigation work. An area that should be explored further for exchange rate risk mitigation purposes is product design. Specifically, Johnstons can focus on alternate fibre compositions to reduce raw material input costs, and develop product designs targeted at markets outside the UK which are currently experiencing relatively high purchasing power against the pound. Additionally, Johnstons can perform exploratory work in the area of digital printing, which would allow for the benefits of product postponement.

CONCLUSIONS

Exchange rate risk is but one of many supply chain challenges faced by Johnstons, but one that poses significant cost, revenue and profit penalties if not managed effectively. This research has begun the process of identifying strategies that can be deployed to mitigate exchange rate risk. Product design appears to be key consideration in enabling Johnstons to further mitigate exchange rate risk.

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