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Supply risk interrelationships and the derivation of key supply risk indicators

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ABSTRACT

Increasing product and service complexity, outsourcing, and globalization lead to complex and dynamic supply networks. Within supply networks, interrelationships and mutual connections among supply risks often create additional challenges for risk monitoring. During normal operation, risk interrelationships remain largely hidden until the occurrence of a specific risk. Understanding these interrelationships is therefore important to increase the effectiveness of risk monitoring. In this paper, the interrelationships between supply risks are quantified and supply risks are categorized according to their role within the system. We follow a network oriented approach as defined by system theory. Our explorative research utilizes data from expert evaluations in selected case companies and emphasizes that strong interrelationships and mutual connections exist between supply risks. We draw on these findings to establish a small and efficient set of key supply risk indicators, making the results highly relevant for executives seeking to improve risk monitoring.

1. Introduction

The inherent presence of risk in all economic action is discussed in a number of papers (e.g. Markmann et al., 2013). Thun & Hoenig (2011) show that increased supply chain complexity and efficiency are among the root causes of a greater vulnerability to supply chain disruptions. In this study, we focus on upstream supply chain risk which we will refer to, in line with the literature, as supply risk.

First, upstream supply chain complexity is reinforced by the reduced degree of internal value added that can be observed in many companies (Talluri & Sarkis, 2002) and by the further integration of globally connected supply networks (Tang & Nurmaya Musa, 2011; Durowoju et al., 2012). The cost for the company is often a reduction in flexibility as well as longer delivery times and greater distances. The probability of supply chain risks and disruptions consequently increases (Juettner, 2005). Based on the complex adaptive system approach (CAS) (Choi et al., 2001), Bozarth et al. (2009) confirm that supply network complexity has a negative impact on enterprise performance and link complexity to an increased exposure to risks.

Second, many companies have implemented efficiency-oriented cost cutting programs in recent years. This results in, for example, the centralization of production and distribution sites, the deployment of lean management methods, and the increasing popularity of single sourcing (Juettner, 2005; Aberdeen Group, 2005). These efforts force the reduction of redundancies and stocks and may create an aggravated risk situation for companies (Tang & Nurmaya Musa, 2011). This is also stressed by Hendricks et al. (2009), who find that firms without operational slack and redundancies in their supply chains experience increased negative stock market reactions.

Given these key drivers that increase both the impact and likelihood of supply risk, greater emphasis is placed on supply risk monitoring (Trkman & McCormack, 2009). Within supply networks, interrelationships and mutual connections between supply risks often create additional challenges for risk monitoring (Hallikas et al., 2004; Rao & Goldsby, 2009). Minor and major events at a specific location in supply networks can lead to large disruptions and entail serious consequences at other locations in the supply chain (Durowoju et al., 2012; Dempsey,

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Table 1
Examples of supply chain disruptions and their respective impact.

Year	Description	Source
1997	A fire in a brake supplier's plant caused a two-week shut-down at 18 Toyota plants and a total loss amounting $195 million.	(Treece, 1997)
1999	An earthquake in Taiwan led to a blackout at semi-conductor suppliers covering more than half of the worldwide production (e.g. memory chips, circuit boards, flat-panel-displays). The following supply shortage caused a revenue loss at Dell, Apple, IBM, Compaq and HP by approximately 5%.	(Hotwagner, 2008)
2000	A fire in a Philips semi-conductor plant caused a three week shutdown at Ericsson and a loss amounting to €400 million.	(Latour, 2001)
2000	Quality problems with the "Wilderness AT" tire at Firestone resulted in a large number of road accidents, 174 reported deaths, and an approximately $2.1 billion for the recall.	(Truett, 2001)
2001	Foot-and-mouth disease in the UK cut off leather supply and caused line stops at Volvo and Ford.	(Sheffi, 2005)
2002	A union strike by less than 100 longshoreman workers disrupted west coast port operations and delayed containers by up to six months.	(Cavinato, 2004)
2007	An earthquake severely damaged Riken, Toyota's major supplier for piston and seal rings, which led to a shutdown of Toyota's Japanese factories and also affected Mitsubishi, Suzuki, and Honda plants.	(Hayashi et al., 2007)
2008	Liquidity and cash flow problems caused the bankruptcy of Plastech, which led to the shut down of 4 Chrysler plants and the loss of millions of dollars.	(Trkman & McCormack, 2009)
2010	Airline flights across the Atlantic were heavily disturbed by the eruption of one of Iceland's volcanos, causing a disruption of global supply chains.	(Field, 2013)
2011	Automakers and electronic manufacturers faced supply shortages of batteries and LCD screens in the wake of the Fukushima disaster in Japan, causing remarkable effects on customer service.	(Field, 2013)

2012), as also shown in Table 1. During normal operations, these interrelationships largely remain hidden until the occurrence of a specific risk (Choi et al., 2001; Surana et al., 2005); this became apparent very recently in the wake of the Fukushima disaster when several automakers and electronic manufacturers worldwide unexpectedly faced shortages of batteries and LCD screens.

To increase the prevention effectiveness of risk monitoring, a clear understanding of these interrelationships is essential (Hallikas et al., 2004). The objective of this paper is to explore interrelationships between relevant operational supply risks in order to appropriately prioritize supply risks for monitoring.

The paper is organized as follows. After this introduction, Section 2 briefly reviews literature on supply risks, their interrelationships, risk frameworks, and risk indicators. Research scope and methodology are defined in Section 3 and draw on principles of system theory and impact analysis, which provide the proper lenses to study connectedness of risks. Section 4 explains data collection and analysis in the course of our explorative study. In Section 5, implications for supply risk monitoring are derived culminating in a small set of key supply risk indicators. Finally, Section 6 concludes and provides an outlook to future research.

2. Literature review

The terms risk and supply risk are not unequivocally defined in the literature. The following is meant to synthesize the most common definitions and theoretical background as a basis for the present paper.

2.1. Supply risk

Various definitions for risk exist. Royal Society (Great Britain) (1992) defines it as "the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge. As a probability in the sense of statistical theory, risk obeys all the formal laws of combining probabilities." A more simplified definition of risk is provided by Spekman & Davis (2004), who define risk "as the probability of variance in an expected outcome."

One risk that companies are exposed to is supply chain risk. This can be subdivided into four dimensions: supply risk, demand risk, product risk, and process risk (Tang, 2006). Supply risk is exclusively located upstream in the supply chain of a company. The criteria most widely used to characterize supply risks are probability and impact. Further, supply risks are frequently subdivided into disruption risk and operational risk (Tang, 2006; Yu et al., 2009; Sawik, 2011). Disruptions are defined as unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain (Svensson, 2000; Hendricks & Singhal, 2003; Kleindorfer & Saad, 2005; Craighead et al., 2007) and that suddenly cut off supply (Hou et al., 2010). Operational risks include recurrent supply uncertainty, for example, the ability in day to day technical support, adherence to delivery schedule, or the quality of delivered parts (Gunasekaran et al., 2004; Ritchie & Brindley, 2007). Our further analysis focuses on operational supply risks, as these are more likely to evolve gradually over time, which is in the main focus of our research.

2.2. Supply risk interrelationships

Network related research has investigated supply risk in the context of supply networks both in terms of inter-company relations and a company's position within the network (Harland et al., 2003). A perspective on inter-company relationships is provided, for example, by Das & Teng (2001), who focus on the relationship between trust and risk in supply networks, and by Zybell (2013), who analyzes the connectedness of partnership management and performance in supply chains from a network perspective.

However, it is also acknowledged that the sources of risk may be related (e.g. Rao & Goldsby, 2009). Therefore it is remarkable that little network related research exists regarding interrelationships between single supply risks that either quantifies the strength of those interrelationships or explores their practical implications (Kleindorfer & Saad, 2005; Heal et al., 2006; Cohen & Kunreuther, 2007). This is rather surprising, as the interrelationships and mutual connections often create additional challenges for risk identification and monitoring (Hallikas et al., 2004; Rao & Goldsby, 2009; Hallikas et al., 2002).