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When does operational risk cause supply chain enterprises to tip? A simulation of intra-organizational dynamics ☆

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ABSTRACT

Interrelationships and feedback loops between different enterprises in a supply chain are widely acknowledged to create additional challenges for risk identification and monitoring. However, each individual manufacturing enterprise is also characterized by interrelationships between its internal operational risks. Our paper investigates these internal interrelationships and provides insights into the operational dynamics of single supply chain enterprises. We use system dynamic simulation and scenario analysis to answer the question: "When does operational risk cause a supply chain enterprise to tip"? We show that some operational risks are significantly more critical than the others, and that this is caused by the interrelatedness of those supply risks. In view of our findings we suggest changes in procurement and risk management activities that shift the focus towards critical operational risks. This will help to create a more stable supply network in the midterm.

1. Introduction

Today, no company can survive in isolation. Every company is linked with other companies, including suppliers and customers, that together form a supply chain [62]. The complexity of these relationships has risen sharply in recent decades [1] as the amount of turnover that a typical manufacturing company spends to purchase goods or services has grown significantly. In the late 1980s, Burt [7] identified this percentage at 60%, which has grown to 70% [19]. By 2025 this percentage is expected to exceed 90% in some industries and commodities, as for example in the automotive industry, the segments electrical drive, and electrics and electronics (as shown in the study "FAST 2025" on automotive value chain structures by Oliver Wyman [45]).

As a result, many companies continuously scan their supplier base worldwide searching for new partnership opportunities. This creates new possibilities for the company, because it enables inclusion of more efficient, innovative, and capable players in the supply chain and helps to increase the efficiency of the company's own operations. However, this development is double-sided, as companies also become dependent on external players. As the enterprises in a supply chain are interrelated, a disruption or shortage at one company can affect the entire chain [62]. Enterprise Risk Management (ERM), which Wu and Olson [81] define as an integrated approach to managing all risks facing an organization, is likely to benefit from the present study as it allows managers to focus on interrelated and hence the most critical risks. Indeed, ERM, amongst other areas, deals with the risks associated with supply chain outsourcing (e.g. [46,47]) and thus has been applied to supply chain contexts. It is crucial to understand the risk that each supplier poses to the own company and to consider unequal levels of supplier reliability in procurement and risk management activities [57,59]. We regard suppliers as subsystems of a supply chain and as systems themselves. Each suppliers' internal processes and structures are exposed to operational risk and experience the same complexity as found in the wider supply chain [2]. Recent literature calls for an increased consideration of these operational risks [17], as they can have an even greater impact on the supplier than external disruptions [71]. Considering that operational risks occur far more frequently than external disruptions, it is clear that their potential for harm is significant.

In supply chain enterprises, interrelationships between operational risks often create additional challenges for risk identification and monitoring [28,27]. During normal operations, these interrelationships largely remain invisible until a specific risk occurs [11,66]. Furthermore, although enterprises need to be subject to monitoring [47], their internal risk interrelationships and dynamics are still a matter of debate [22]. Therefore, to increase risk prevention and the effectiveness of risk monitoring, an understanding of these interrelationships is essential [27].

In light of the above, our research focuses on operational risk at single supply chain enterprises. The central question of this paper

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is: “When does operational risk cause a supply chain enterprise to tip”? Our approach is inspired by Malcolm Gladwell's bestseller “The Tipping Point” [20], in which he emphasizes the existence of a point that, when reached, produces the incredible spike or fall of a system (e.g. the unexpected popularity of Hush Puppies, the tremendous drop of New York City's crime problem in the 1980s, or the spread of HIV). His book reveals how small, nearly invisible differences between two seemingly equal events can cause one system to tip and another not.

In this paper we look more closely at the risk that emerges from the stability or instability of single enterprises in a supply chain with the objective of enhancing risk management in the upstream supply chain. We provide a framework that captures an enterprise's operational supply risk and develop a system dynamics model to represent its internal dynamics. Based on this, we simulate the impact on the system of the occurrence of a supply risk and ask whether some risks are more likely than others to “tip” the system – which in this case would mean causing the enterprise to collapse, thus causing a disruption in the wider supply chain.

The remainder of this paper is organized as follows: Section 2 briefly reviews the existing literature on supply risk, supply risk in individual supply chain enterprises, and their interrelationship. The research methodology is defined in Section 3 and draws on principles of system theory and system dynamics simulation, which provide the framework for analyzing the network behavior of operational risks. In Section 4 we develop the system dynamics framework and validate our simulation model. In Section 5 we present the results of our scenario simulation and in Section 6 derive managerial implications. Finally, in Section 7 we draw conclusions and provide outlooks for further research.

2. Literature review

Our research touches on three fields of literature: supply risk in general, supply risks in a single enterprise of a supply chain, and the interrelationships between supply risks.

2.1. Supply risk

Various definitions for risk exist. The Royal Society (Great Britain) [56] 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 and Davis [64], 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 [71]. 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 [70,84,60]. Disruptions are defined as unplanned and unanticipated events that disrupt the normal flow of goods and materials within a supply chain [68,31,37,15] and that suddenly cut off supply [32]. 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 [25,54]. Our further analysis focuses on operational supply risks, as these are more likely to evolve gradually over time, which is in the main interest of our research. In parallel, we identify the operational risks that are most critical to the supply chain and hence support shifting the focus from considering risks in isolation to comprehensive risk management as it is advocated by the research stream of ERM [4,81].

2.2. Supply risk from individual supply chain enterprises

Companies need to evaluate the enterprises in their supply chains not only in terms of price competitiveness, but also in terms of potential product failure, bankruptcy, or even political risk [47]. Their unequal reliabilities need to be considered for effective supply chain risk management [57,59]. The effects of disruptive events on supply chain decision making have already been studied. For example, Yu et al. [84] consider disruptive events at single supply chain enterprises in deciding between single and multiple sourcing; Ruiz-Torres and Mahmoodi [57] and Sawik [60,59] deal with the unequal reliability of different supply chain enterprises under the presence of supply chain disruptions.

However, operational risk at individual supply chain enterprises is rarely taken into account for decision making. This seems remarkable, given how much literature exists on the relevant types and sources of operational risk and the various risk frameworks that have been developed [42,64]. Relevant research streams are, for example, the concept of supply chain vulnerability [12,14] and literature on performance measurement [40].

For this paper, we draw on the framework developed by Peck [49,50], which provides a broad, holistic view of all types of supply risks at a single enterprise. Peck suggests that supply risks operate at several different levels, are intricately linked as elements of a system, and can be described in four discrete levels of analysis:

- Level 1-value stream/product or process.
- Level 2-assets and infrastructure dependencies.
- Level 3-organizations and inter-organizational networks.
- Level 4-the environment.

  Level 1 represents the direct flow of information and materials between different supply chain partners which is driven by the interconnected entities. It is the physical connection that counts on this level whereas it is often compared to a “pipeline”. Problems on this level can be directly and promptly recognized by the next supply chain partner downstream. Main risks are commercial consequences due to inefficient supply chain performance.

  Level 2 provides the assets and infrastructure that are needed to facilitate the flows on level 1. These range from commercial assets such as company buildings, production facilities and tools or logistic hubs to communication and information technology such as ERP systems, server facilities or call centers. Those assets are interconnected by public infrastructure such as streets or telephone cables. The stability on this level is significantly driven by the competence of workers, employees and managers. Discrepancies on this level are likely to affect level 1 within short notice.

  Level 3 accommodates the public or commercial organizations that own the assets on level 2 and facilitate the flow of information and materials on level 1. These are linked by inter-organizational relationships and communication, affected by economic power and dependency. Deteriorations on this level can cause wide reaching and long lasting deficiencies on both lower levels.

  Level 4 is the macroeconomic environment in which the companies on level 3 operate. Relevant characteristics of this level are political, economic, social and technological conditions as well as the natural environment. Developments on this level can only seldom be influenced by the operating companies, however, are likely to affect all lower levels.