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A comprehensive decision-making model for risk management of supply chain

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ABSTRACT

Risk management of a supply chain (SC) has a great influence on the stability of dynamic cooperation among SC partners and hence very important for the performance of the SC operations as a whole. A suitable decision-making model is the cornerstone for the efficiency of SC risk management. We propose in this paper a decision-making model based on the internal triggering and interactive mechanisms in an SC risk system, which takes into account dual cycles, *the operational process cycle* (OPC) and *the product life cycle* (PLC). We explore the inter-relationship among the two cycles, SC organizational performance factors (OPF) and available risk operational practice (ROP), as well as the risk managerial elements in OPC and PLC. In particular, three types of relationship, bilateral, unilateral and inter-circulative ones, are analyzed and verified. We build this dynamic relation into SC risk managerial logic and design a corresponding decision-making path. Based on the *analytic network process* (ANP), a methodology is designed for an optimal selection of risk management methods and tools. A numerical example is provided as an operational guideline for how to apply it to tailor operational tactics in SC risk management. The results verify that this strategic decision model is a feasible access to the suitable risk operational tactics for practitioners.

1. Introduction

With the logic integration of numerous risk managerial factors in an SC risk system, we commit to a comprehensive risk decision-making model to improve stability of decision-making process and pertinence of risk measurements selected. We explore an analysis path for the framework based on the operational process cycle (OPC) and the product life cycle (PLC), as well as SC organizational performance factors (OPF) and available risk operational practice (ROP). According to the dual-cycle' role as a main clue of the decision-making process, the relationship of relevant risk managerial clusters is studied logically as well as ones among SC's performance criteria and dual-cycle. Feature more we build the influence and correlation between OPC and PLC into the decision-making process. Thereafter, we design a decision-making model and selecting methodology for the model based on ANP theory. It would provide a deeper insight on SC risk management for practitioners involved.

Various factors contribute to the complexity of an SC risk system (Copra & Sodhi, 2004). Too many suppliers may make it very difficult to maintain a stable relationship. Cross-production processes increase complexity and uncertainty. A long logistics cycle affects availability and increases the risk of inventory obsolescence. Expanded product catalogues make service supporting system more complex and hence increase the cost and undermine its responsiveness.

There has been much research in the literature on the uncertainty and risks in SC management. Lin, Chang, Hung, and Pai (in press) developed a fuzzy system to simulate vendor managed inventory (VMI) that represents dynamic relationship in SC deeply. Alex (2007) provided a novel approach to model the uncertainties involved in the supply chain management using the fuzzy point estimation.

The work of Riddalls and Bennet (2002) generates generic conclusions about the dynamics of characteristic supply chains and promotes an awareness of the dynamical nature of supply chains and their drivers in broad terms. Particularly, they demonstrated how stock-outs in lower echelons can create a vicious circle of unstable influences in the supply chain. Copra and Sodhi's (2004) research also highlights managers have to tailor their balanced and effective risk reduction strategic while encountering various category of risk in SC.

Tang (2006) suggested that robust strategies for mitigating supply chain disruptions and highlighted that these strategies not only can manage the inherent fluctuations efficiently regardless of the occurrence of major disruptions but also lead to a more resilient supply chain in the face of major disruptions.

Huchzermeier and Cohen (1996) showed that global coordination, logistics and postponement can enhance operational

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flexibility and reduce the system risk effectively. Thonemann and Bradley (2002) found that changes in manufacturing processes and in the SC structure can improve SC performance. Nagurney, Cruz, and Matsypura (2003) developed a model for the modelling, analysis and computation of solutions to global supply chains.

On the other hand, Kouvelis and Rosenblatt (2002) demonstrated the pervasive effects of financing, tariffs and taxation on shaping the manufacturing and distribution network of global firms. Goh, Lim, and Meng (2007) developed a model, based on the Moreau–Yosida regularization, to optimize the trade-off between profit and risk for a multi-stage global supply chain network.

While it is good to have an increasing number of choices for risk management methods and tools in practice (Huchzermeier, 2000), how to tailor them with their various functionalities and features is still a big challenge. In this paper, we respond to this challenge by proposing a decision-making model and a methodology for SC risk management.

The paper is organized as follows. In Section 2, various risk forms in SC management are considered in terms of performance. Possible reasons of their fluctuation and tactics are also analyzed based on SC operational processes, which include procurement, production, marketing, logistics and service. We are led to questions of how to incorporate an operational process into a product life cycle and what SC risk management methods should be chosen. In Section 3, we explore a basic dual-cycle model of SC risk management based on its operational process cycle (OPC) and product life cycle (PLC). With the basic decision-making model, in Section 4, we analyze some interactive mechanisms between the OPC and the PLC. Different value-added activities in SC operational processes have different risk features and influences at a special period of PLC. At the same time, the intrinsic features of each product life stage also affect the OPC and its value-added activities. In Section 5, based on the notion of an analytic network process (ANP) (Saaty, 1996), we design an analytic model for selection of an optimal combination of risk management methods. With this model, we carry out a quantitative analysis of the aforementioned mutual and multilateral influences among different risk clusters and elements. In Section 6, we make some concluding remarks on the strengths and limitations of our proposed decision-making model.

2. Analysis of supply chain risk forms and tactics

2.1. Supply chain risk forms

Grey and Shi (2001) and Smith and Huchzermeier (2003) showed that a clear recognition of risk features is the very beginning of effective SC risk management, as illustrated in Fig. 1. By keeping a clear map in mind on the variety and inter-connectedness of SC risk, managers can tailor their operational tactics for the companies (Copra & Sodhi, 2004). Risk features may vary along SC operation processes. However, there are several ultimate forms of SC risks: quantity, cost, quality and time. These would be explained in turn next.

Uncertainty in quantity influences SC operations thoroughly. A false prediction on safety stock may lead to a shortage of parts and components. On the impact of order volatility, Childerhouse, Disney, and Towill (2008) demonstrated the behavior of cause and effect in the European automotive SC system via quick scan audit methodology (QSAM) supplier-OEM studies.The reliability of production and service would be seriously affected by a disruption of supply. Furthermore, it may undermine vendors' initiatives and enterprises' image, resulting in a declined market share. A deficient plan restricts production, which may result in production bottle-necks and excessive inventories. Mistakes of prediction on demands may either lead to loss of opportunities or excessive end-product inventory. False designs on SC structure and operations are the very reason of an increased volume in store while an unreasonable layout of inventory undermines the SC responsiveness and profitability (Ha, Li, & Ng, 2003).

Cost also has a wide range of influences. The fluctuation of procurement cost may intensify the swing scale of revenue and profit (Ray, Li, & Song, 2005). Too much various slack in production system, such as back up production utilities, too much shift-work employees and long lead-time, always increases production cost. An unreasonable decision on price will lead to a loss of market share and an increased inventory. A defective service supporting system may increase the frequency of emergency service, which is the very reason of a climbing logistics cost.

Quality may influence SC operation in many ways. A low-level quality of components and parts in procuring process will decrease the outcome of production and affect consumer experience, which in turn would harm sales and image of the enterprise. Furthermore, it always increases the cost of warranty and after-sale service. Failures on an SC structure and operational process design are the very reason of a low-level flexibility (Graves & Tomlin, 2003), which is the obstacle to enforcing just-in-time (JIT) and vendor management inventory (VMI). The quality of after-sale supporting system influences customer satisfaction. Ultimately, a low-level quality will speed up the obsolescence of products.

As a risk form, time has various influences on an SC. In terms of new product development program, outdated technology and orientation make enterprises lose its competitive edge (Kleindorfer & Partovi, 1990). Competence of timely delivery is affected seriously by the fluctuation of a production cycle. Inventory depreciation essentially owes to obsolescence. An unreasonable profile of inventory may even make obsolescence and degeneration from bad to

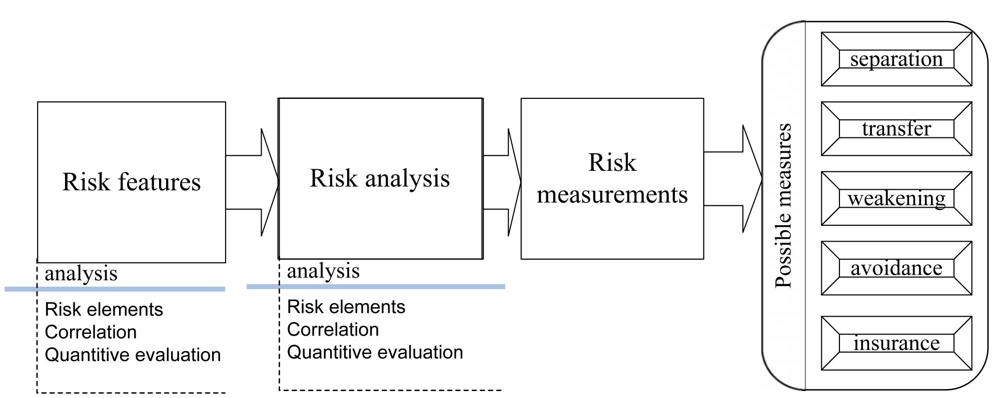

Fig. 1. Basic decision-making model for SC risk management.