Expert Systems With Applications xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Expert Systems With Applications

journal homepage: www.elsevier.com/locate/eswa

A software application for rapid risk assessment in integrated supply chains

Q1 Faisal Aqlan*

Department of Industrial Engineering, Pennsylvania State University, The Behrend College, Erie, PA 16563, United States

ARTICLE INFO

Keywords:
Rapid risk assessment
Probability theory
Fuzzy logic
Risk priority matrix
Integrated supply chains

ABSTRACT

Supply chain risk management (SCRM) has become a critical component of supply chain management with the movement to global supply chains and the increasing occurrence of internal and external risk events. Effective management of supply chain risks requires a comprehensive yet rapid assessment of all the risk factors in the supply chain and their potential impacts. This paper presents a software application framework for rapid risk assessment (RRA) in integrated supply chains. The proposed framework combines qualitative and quantitative methods to assess and prioritize the risks. Qualitative methods are based on surveys used to collect the risk probability and impact data for the main agents in the supply chain (*i.e.*, supplier, customer, manufacturer, etc.). Quantitative methods are based on probability theory and fuzzy logic. Risks are calculated for each agent in the supply chain and are then aggregated per product type. The proposed RRA tool was tested in a manufacturing environment to assess the validity of the proposed framework. Results from the case study showed that the assessment obtained by the proposed framework agrees with what the risk management experts think about the risk levels and priorities in the company.

1. Introduction

Supply chain management can be defined as "the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole" (Christopher, 2011). The goal of supply chain management is to manage the relations among supply chain components in order to achieve more profitable outcomes for all supply chain parties. Supply chain performance may be negatively impacted by of the occurrence of risk events in different stages of the supply chain system. The management of such events is known as supply chain risk management (SCRM), which has become a critical part of the organizational strategy. SCRM has gained more attention with the movement to global supply chains and the increasing number of disruptions that affect the performance of supply chains. SCRM focuses on the identification of potential risks and disruptions in the supply chain and developing mitigation strategies to reduce the impact of these disruptions and risks on supply chains.

An essential step for risk management is the understanding of the different categories of risks, and the events and conditions that drive these risks. The goal of SCRM is to prepare the company to be able to respond to different types of risks in such a way that minimizes the impact on its operations. The art of risk management is to "identify risks specific to an organization and to respond to them in an appropriate way" (Merna & Al-Thani, 2005). For risk management to be effective, all different levels of the organization need to be considered. According to Blackhurst and Wu (2009), most of the definitions of SCRM include the following activities: (1) Risk identification and modeling (2) Risk analysis, assessment and impact measurement (3) Risk management (4) Risk monitoring and evaluation (5) Organizational and personal learning including knowledge transfer. Like other management approaches, SCRM requires good quality of knowledge, abilities, experiences, and skills. It ensures that the principles established by managers are applied to logistics' risk (Waters, 2007).

Risk events represent a daily challenge to supply chain and logistics management. The ability to respond to and mitigate these risk events puts the company ahead of its competitors and reduces the expected long-term damage to its business. Risk exists in supply chain because of the uncertainty about future risk events, which can appear at any time point in the supply chain. Risks in the supply chain can be classified into five types: demand risk, supply risk, process risk, planning and control risk, and environmental risk. These five types of risks can be further classified into: internal to the organization (process risk and planning and control risk), external to the organization but internal to the supply chain (demand risk and supply risk), and external to the supply chain (environmental risk). To manage the risks and minimize their impact on the organization, risk mitigation strategies are implemented. The selection of risk mitigation strategies

* Tel.: +1 814 898 6945.
E-mail address: fua11@psu.edu

http://dx.doi.org/10.1016/j.eswa.2015.08.028
0957-4174/

depends on risk type and organization's budget. Chopra and Sodhi (2004) listed the following risk mitigation strategies: adding capacity, adding inventory, having redundant suppliers, increasing responsiveness, increasing flexibility, aggregating or pooling the demand, increasing capability, and having more customer accounts.

Effective management of supply chain risks requires a comprehensive yet rapid assessment of all of the risk factors in the supply chain and their potential impacts. Quantitative risk assessment models have been proved to be an effective and efficient methodology for quantitatively evaluating risks in supply chains. Risk management software that implements quantitative models for risk assessment is also available. However, most of these software tools are commercial and they do not consider the different aspects of supply chain risks.

The paper is structured as follows. Section 2 discusses the literature related to risk assessment in integrated supply chains. In Section 3 a conceptual framework for rapid risk assessment in integrated supply chains is laid out, characterizing the main types of risk that are encountered by participants within those supply chains, and characterizing the range of measures that can be taken to manage such risks. Section 4 discusses the proposed software application. A detailed description of the software main components is provided. Section 5 presents a case study from a real manufacturing integrated supply chain. Finally, conclusions and future work are discussed in Section 6.

2. Related literature

The management of supply chain risks has received more attention with the increase in the number of risk events such as international terrorism, economic crises, and wars (Lim, 2010; Sheffi, 2002). Different frameworks for supply chain risk management and mitigation have been proposed in the literature. For example, a framework that considers the effects of risk sharing and information management in supply chain networks was developed by Wakolbinger and Cruz (2011). Diabat, Govindan, and Panicker (2012), discussed the analysis and mitigation of risks in a food supply chain. Chen, Sohal, and Prajogo (2013) developed a collaborative approach for mitigation operational risks in supply chains including: supply risks, demand risks, and process risks. A framework for product quality risk and visibility assessment was presented by Tse and Tan (2011). The study argues that better visibility of risk in supply tiers could minimize quality risks. One main limitation of the literature on supply chain risks is that the most studies do not consider risk factors and risk interconnections when risks are calculated and assessed.

Many researches utilized qualitative and quantitative techniques to study supply chain risks. Wu, Blackhurst, and Chidambaram (2006) developed a quantitative model for inbound supply risk analysis based on Analytic Hierarchy Process (AHP). The study also built a prototype computer implementation system and tested it using an industry example. A framework for modeling and analyzing supply chain risks based on timed Petri nets was proposed by Alpan and Gonca (2010). An optimization model for finding the optimal number of suppliers under the risk of supply disruption was developed by Sarkar and Mohapatra (2009). Goh, Lim, and Meng (2007), proposed a stochastic model for managing risks in global supply chains including: demand, supply, disruption, and exchange risks. Simulation modeling has also been used to study and analyze supply chain risks. Schmitt (2009) discussed the use of discrete-event and Monte Carlo simulation methods to quantify supply chain disruption risks.

Uncertainty in supply chain risk assessment causes the decision making to be a complex process. Risks occur in supply chains because of uncertainty about the future (Waters, 2007). Reduction of uncertainty in managing supply chain risks has an economic value and it improves the accuracy of risk management decisions. According to Bogataj and Bogataj (2007), uncertainty level depends on the type and amount of information that is available to estimate the risk likelihood and its impact. In order to reduce the uncertainty in supply chain risks, fuzzy set theory, probability theory, and knowledge management principles can be utilized. The use of fuzzy logic methods for risk identification and modeling in supply chains was presented in Ebrahimnejad, Mousavi, and Seyrafianpour (2010). A fuzzy multi-criterion model for the assessment of suppliers in supply chains was developed by Hamidi (2011). Aqlan and Ali (2014), combined Lean principles with fuzzy logic for risk assessment in chemical industry. An integrated framework for supply chain risk assessment based on fuzzy logic was proposed in Aqlan and Lam (2015a).

Software tools for risk management have been discussed in the literature. For example, Fugini, Teimourikia, and Hadjichristofi (2015) presented a web-based cooperative tool for risk management with adaptive security utilizing event-condition-action meta-rules. Stornetta, Engeli, Zarn, Gremaud, and Sturla (2015) developed a risk management tool to prioritize chemical hazard-food pairs. The tool is based on the derivation of a "Priority Index" (PI) that is based on the ratio of the potency of the hazard and the consumer exposure. Hochrainer-Stigler, Mechler, and Mochizuki (2015) presented a risk management tool for tackling country-wide contingent disasters. One major limitation of the literature on supply chain risk management is the lack of rapid and comprehensive assessment methods to quantify and assess the risks. In addition, most of the available commercial softwares for supply chain management do not provide a comprehensive quantitative assessment of the risks. They may also require a long time to perform the risk assessment process.

This study proposes a framework and a software implementation for a comprehensive assessment of risks in the integrated supply chains. The proposed framework considers the factors that cause the risks of the different agents in the supply chain (i.e., suppliers, customers, manufacturers, etc.).

3. Rapid risk assessment framework

The proposed methodology for Rapid Risk Assessment (RRA) is shown in Fig. 1. The proposed framework integrates both qualitative and quantitative risk assessment methods. Qualitative risk assessment is based on survives and interviews while quantitative analysis uses probability theory and fuzzy logic. The quantitative part of the framework provides a new approach for risk assessment in integrated supply chains. The RRA framework starts with identifying the main agents in the supply chain (i.e., suppliers, manufacturers, distributers, customers, etc.) and their interactions. The type and number of agents are based on the structure of the integrated supply chain. Once the agents of the supply chain and the interaction among them are identified, risk factors are determined for each agent. Risk factors data is collected through surveys distributed to the risk management experts. More risk factors data can also be collected based on historical (and current) data and using simulation techniques. For each agent in the supply chain, risk factor data are collected for probability and impact of the risk and the current mitigation strategies. The collected data for the risk factors is used to calculate the aggregated risk values for the agents. Risk Priority Matrix (RPM) is used to calculate the risk per risk type and per each agent in the supply chain. Based on the bill of the materials (BOM) for product and the supply chain agents involved in producing the product and delivering it to the customer, risk is aggregated per product. This allows for comparing the risks associated with the different product types in the integrated supply chain. The following sections discuss the steps of the RRA framework in detail.

3.1. Identify main agents in the supply chain and their interactions

The main agents in the supply chain and the interaction among them can be identified using on the Supply Chain Operations Reference (SCOR) model. The SCOR model is a framework for evaluating

Please cite this article as: F. Aqlan, A software application for rapid risk assessment in integrated supply chains, Expert Systems With Applications (2015), http://dx.doi.org/10.1016/j.eswa.2015.08.028