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Resilient supplier selection and order allocation under operational and disruption risks

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A B S T R A C T

This study proposes a bi-objective mixed possibilistic, two-stage stochastic programming model to address supplier selection and order allocation problem to build the resilient supply base under operational and disruption risks. The model accounts for epistemic uncertainty of critical data and applies several proactive strategies such as suppliers' business continuity plans, fortification of suppliers and contracting with backup suppliers to enhance the resilience level of the selected supply base. A five-step method is designed to solve the problem efficiently. The computational results demonstrate the significant impact of considering disruptive events on the selected supply base.

1. Introduction

Today's competitive global market is forcing companies to outsource some of their products and services. Outsourcing can help companies to reduce costs and enhance their competitive capabilities through focusing on their core competencies (Schoenherr et al., 2012). A group of suppliers from which a company purchases goods and services is called the "supply base". Selecting the best supply base is a challenging decision in outsourcing and it plays a critical role in the success of supply chains; especially global ones (Bhutta and Huq, 2002). The Supplier Selection and Order Allocation (SS&OA) problem is a complex decision problem involving multiple tangible and intangible criteria (Aissaoui et al., 2007; Ho et al., 2010). It aims to select the best portfolio of suppliers and to optimally allocate the buyer's total demand among selected suppliers to satisfy different purchasing criteria. Other considerations include meeting the required minimum order quantity and the limited capacity of each supplier. Traditionally, the SS&OA problem has accounted for cost, quality and delivery time (i.e. QCD measures). However, today's global supply chains are more prone to unexpected natural and man-made disasters such as floods, volcanic eruptions, earthquakes, tsunamis, fires, transport accidents and labor strikes. In the wake of Japan's earthquake in 2011, Apple suffered from shortage of key parts for its iPad 2 including its flash memory and super-thin battery which were exclusively manufactured by Apple Japan (BBC News, 18 Mar 2011). Japan's 2011 earthquake-triggered tsunami and the Icelandic Volcano in 2010 disrupted global supply chains including the automotive sector and retail supply chains in UK

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(Massey, 7 April 2011; Hall, 16 Apr 2010). Auto maker Nissan was hit the hardest in the aftermath of Japan's 2011 earthquake because of its dependence on a factory in the earthquake zone that would supply 12% of its engines (BBC News, 18 Mar 2011). This forced the Nissan's UK Sunderland plant to shut down for three days because of shortage of parts from Japan (Massey, 7 Apr 2011). More recently, hurricane Sandy caused massive disruptions in US supply chains (Burnson, 30 Oct 2012). These events demonstrate that supply chain disruptions are detrimental to businesses from the lost productivity and revenue standpoint. As such, with the growing reliance on global sourcing in recent years and consequently the increase in the likelihood of disruptive incidents, providing a reliable level of resilience to the supply base to protect the buyer from shortages and disruption in the supply flow is all the more critical.

Generally speaking, supply chain risks can be divided into two risk categories: Operational and Disruption (Tang, 2006). Operational risks refer to those inherent uncertainties that inevitably exist in supply chains. These include, but are not limited to, customer demand and cost rate uncertainty, and also supply uncertainty due to operational difficulties like equipment failure, power outage and key personnel absence. Accounting for inherent uncertainty in the critical input data such as demand, cost, and capacity parameters through uncertainty programming approaches (e.g. fuzzy/possibilistic/stochastic/robust programming) is one way to deal with operational risks that is common in the literature (Sawik, 2011). Disruption risks refer to the major disruptions caused by natural, man-made or technological threats such as earthquakes, floods, terrorist attacks or employee strikes. Notably, operational risks are caused by medium to high likelihood, low impact as-usual events which have only short term negative effects while disruptions are caused by low likelihood, high impact disruptive events which may have short or long term negative effects on the system.

This paper aims to develop a new decision model to build resilient supply bases for global supply chains in response to uncertainties arisen from major disruptions caused by natural and man-made disasters and operational risks. To this end, a bi-objective mixed possibilistic, two-stage stochastic programming model with a new resilience objective is proposed in which several proactive strategies such as fortifying suppliers at different discrete levels and suppliers' business continuity plans are taken into account. Noteworthy, documented collection of procedures and information that is developed, compiled and maintained in readiness for use in an incident to enable an organization to continue to deliver its critical activities at an acceptable pre-defined level are called business continuity plans (ISO 22301, 2012). Furthermore, business continuity management is a management process which identifies possible internal and external threats/risks and their impact to business processes and provides a framework for organizational resilience (ISO 22301, 2012). In this way, implementing a business continuity management system (BCMS) within an organization can protect the organization against various disruptive events by providing suitable business disaster recovery/continuity plans for identified critical business processes/functions proactively (Sahebjamnia et al., 2015; Torabi et al., 2014). To the best of our knowledge, this paper is the first one in the literature which accounts for business continuity related concepts/measures in a supply chain planning decision problem especially in a SS&OA problem.

The remainder of the paper is organized as follows. Section 2 provides a review of the related literature. The problem description and proposed model with developing a new resilience objective are respectively elaborated in Sections 3 and 4. The solution procedure is presented in Section 5. Section 6 presents some numerical examples along with their computational results. Finally, Section 7 draws some conclusions from this study.

2. Literature review

A review of the related literature is presented below in two distinct but related research streams: supply disruption/risk management and resilient supply chains.

2.1. Supply disruption/ risk management

Over the past few decades, especially after 11th September 2001, risk management has received increasing attention from both practitioners and academia so that around fifty tools and methodologies have been developed for risk management (Shi-Cho et al., 2008). Chopra and Sodhi (2004) categorised potential supply chain risks into nine categories: (a) Disruptions, (b) Delays, (c) Systems, (d) Forecast, (d) Intellectual property, (e) Procurement, (f) Receivables, (g) Inventory, and (h) Capacity. They identified events and conditions that drive these risks and the mitigation strategy against each kind of risk. In this section, we review the most relevant published works accounting for disruption risks and common mitigation strategies used in the supply side of a supply chain especially those addressing SS&OA problem under disruption.

Dual/multiple sourcing instead of single sourcing is a common approach to decreasing supply disruption risk in the literature. Although single sourcing is less expensive than multiple sourcing in normal conditions, supplier disruption in single sourcing case can result in greater loss than dual/multiple sourcing. Accordingly, some works address determining the optimal number of suppliers in the presence of disruption risks. For example, for the first time, Berger et al. (2004) assumed two types of catastrophes: ''super-events'' which affect many/all suppliers and ''unique events'' which disrupt a single supplier. They considered the financial loss caused by disasters and the operating cost of working with multiple suppliers and proposed a decision tree to decide on optimal number of suppliers by minimizing the expected cost function. Ruiz-Torres and Mahmoodi (2006) developed an extension to the Berger et al. (2004) and presented a decision model for optimizing the allocation of demand across a set of suppliers by considering three key cost factors: the expected losses due to supplier