Global Supply Chain Network Design Incorporating Disruption Risk

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ABSTRACT

Supply chain networks have expanded globally in today’s business environment due to cost efficiencies, advanced technology, and market growth. This expansion makes the supply chains more vulnerable to disruption risks in different countries. A disruption in one country can cause serious global impacts. In this article, we formulate a multi-criteria optimization model for supporting strategic supply chain network design decisions. The model considers disruption risk of supply chain components (i.e., facilities and transportation links) as well as profit and customer responsiveness as conflicting criteria. This consideration is important since disruption at any supply chain component may lead to the disruption of the entire supply chain network. We apply goal programming (GP) techniques to handle multiple and conflicting network design objectives. We also present a numerical example to illustrate how to incorporate disruption risk when making strategic supply chain decisions. The results demonstrate how supply chain network designs that over emphasize profit may include inexpensive supply chain components with high disruption risk. Therefore, more attention must be paid to managing potential disruptions and designing supply chain networks that balance profit and risk. We discuss tradeoffs among multiple design solutions and identify opportunities for future research.

Keywords: Disruption Risk, Goal Programming, Multi-Criteria Optimization, Supply Chain Disruption, Supply Chain Network Design

INTRODUCTION

Supply chain networks have expanded globally in today’s business environment. The geographies, regulations, and ecosystems associated with different countries have increased the complexity associated with global supply chain management and made the global supply chain more vulnerable to disruptions (Ravindran & Warsing, 2013). Disruption in one country can significantly impact global supply chains. From a supply chain risk perspective, disruption risks due to natural disasters in each country or region are varied; for instance, Asia experiences high economic losses from earthquake, tsunami, and floods, while America’s economic

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losses are primarily due to storms and hurricanes (Guha-Sapir, 2012). The vulnerability of supply chain components to disruptions also differs based on their roles in the supply chain network (Kungwalsong & Ravindran, 2012; 2013). Risk identification and mitigation strategies also vary among countries. Countries with efficient, transparent, and accountable governments engage in both pre-disaster planning and post-disaster recovery planning, making them better able to respond to natural disasters than the countries with corrupt governments (Kellenberg & Mobarak, 2008; Stromberg, 2007; Ye & Abe, 2012). A study by The Harvard Business Review Analytic Services (Harvard Business Review, 2011) showed that natural disasters have been among the significant risks over the last three years. Furthermore, the International Disaster Database (2012) indicates that natural disasters have occurred more frequently in recent decades. Supply chain network designs that emphasize cost and customer satisfaction seem inadequate for supply chain resiliency in such complex environment. Plausible disruptions should be considered in order to design a robust value-creating network (Klibi & Martel, 2012). Table 1 presents examples of significant disruptive events and their financial impacts to global supply chains.

Supply chain decisions can be classified as strategic, tactical, and operational, and disruptions should be treated differently for each level. In this paper, we focus specifically on strategic supply chain network design decisions and demonstrate how to incorporate disruption risks in order to balance disruption risk and business efficiency. We apply the disruption risk assessment framework proposed by Kungwalsong and Ravindran (2012; 2013) to quantify the disruption risk score of each facility and transportation link based on hazard, vulnerability, and risk management factors. The quantified risk scores are used as input parameters for the supply chain network design model. We formulate a multi-criteria optimization model to support strategic supply chain network design decisions. The model considers profit, customer responsiveness (demand fulfillment and delivery), and disruption risk of supply chain components (i.e., facilities and transportation links) as the design criteria. Goal Programming (GP) techniques are used to handle the multiple conflicting objectives. Using the model, companies can evaluate tradeoff between benefits and risks among various design solutions.

The remainder of this paper is organized as follows. Section 2 presents a review of the relevant literature. Section 3 introduces the multi-criteria optimization model for supporting supply chain network design decisions. Section 4 discusses solution techniques and presents a numerical example of the supply chain network design problem. Sections 5 and

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**Table 1. Disruptive events and their financial impacts (from Kungwalsong and Ravindran, 2012)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Event</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>United states</td>
<td>West coast port strike</td>
<td>$11-$22 billion</td>
</tr>
<tr>
<td>2008</td>
<td>Thailand</td>
<td>Airport closure</td>
<td>$8.5 billion</td>
</tr>
<tr>
<td>2010</td>
<td>Worldwide</td>
<td>Piracy and hijacking of ships</td>
<td>$7-$12 billion</td>
</tr>
<tr>
<td>2011</td>
<td>Japan</td>
<td>Earthquake/tsunami</td>
<td>$210 billion</td>
</tr>
<tr>
<td>2011</td>
<td>Thailand</td>
<td>Floods</td>
<td>$30 billion</td>
</tr>
<tr>
<td>2011</td>
<td>New zealand</td>
<td>Earthquake</td>
<td>$20 billion</td>
</tr>
<tr>
<td>2011</td>
<td>United states</td>
<td>Tornado</td>
<td>$15 billion</td>
</tr>
<tr>
<td>2011</td>
<td>Australia</td>
<td>Floods</td>
<td>$7 billion</td>
</tr>
<tr>
<td>Annual</td>
<td>Egypt</td>
<td>Ship re-routed to avoid piracy</td>
<td>$642 million from suez canal fees</td>
</tr>
</tbody>
</table>
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