Transportation Research Part E 115 (2018) 87–109

Contents lists available at ScienceDirect

Transportation Research Part E

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

Designing a resilient competitive supply chain network under disruption risks: A real-world application

Ali Ghavamifar[a], Ahmad Makui[b], Ata Allah Taleizadeh[a,*]

[a] School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

ARTICLE INFO

Keywords:
Competition
Disruption risks
Bi-level programming
Compromise programming
Benders decomposition

ABSTRACT

We address an intra-supply chain competition where a producer and resellers competing to achieve their goals, while taking into consideration the uncertainties and disruption risks. We utilize a bi-level multi-objective programming approach for designing a competitive supply chain network. A hybrid solution approach, combining the compromise programming and Benders decomposition methods, is developed to solve the model. Furthermore, an efficient inequality constraint is proposed to cope with the computational complexity of the bi-level model. To explore the practical application of the model, a real-world case example is discussed. Finally, the scalability of the solution approach is illustrated for large-scale problems.

1. Introduction

Besides shifting consumer behavior, the intense competition and globalization of supply chains (SCs) are leading to substantial shifts in the function of the SCs. In a traditional supply chain network design (SCND) problem, the main goal is connecting the supply and demand at an optimal cost, benefit, or service level, but nowadays, SC planning is more complicated (Farahani et al., 2014). The major trends in the business market such as outsourcing, globalization, and customization create tremendous complexities in the SCs. Moreover, the global SCs are much more sensitive to large-scale natural disasters, terrorist attacks, electrical blackouts, and operational failures (Snyder et al., 2015). The findings from a study conducted show that 25% of the managers in 600 financial executive firms believe that in comparison with other risks, SC risks have the most effect on the SC's profitability and revenue growth (Smyrlis, 2006). Hendricks et al. (2009) introduced three major issues related to SC disruption risks, namely the primary factors influencing the frequency and probability of disruptions (Chopra and Sodhi, 2004; Tang, 2006; Craighead et al., 2007), economic consequences of disruptions (Latour, 2001; Hendricks and Singhal, 2005b), and the impact of SCs strategies and structure on reducing the frequency and negative consequence of disruption (Lee, 2004; Tomlin, 2006). The World Economic Forum's[1] report emphasizes on building resilient SCs. It indicates that huge disruptions in the SCs decline the share price of the affected companies by an average of seven percent. It has also determined that 80 percent of companies perceive the better protection of the SCs against the treats as a priority (Global Risks Report, 2012). In the view of risk management, the main threats to SCs are natural disasters (i.e. earthquakes, floods, and extreme weather conditions) and man-made disasters (i.e. fires, terrorist attacks, and labor strikes). Both of these disasters threaten the ability of logistic providers, manufacturers, suppliers, and other beneficiaries of the SCs to maintain a state of business continuity, which is their ultimate goal with no business tolerance for times of disaster (Snyder et al., 2006).

* Corresponding author.
E-mail addresses: Ali.ghavamifar@ut.ac.ir (A. Ghavamifar), amakui@iust.ac.ir (A. Makui), taleizadeh@ut.ac.ir (A.A. Taleizadeh).

[1] The World Economic Forum is an international organization for public–private cooperation prepares the Global Risks Report as a collaborative effort since 2006. It reflect the views of leaders from their various communities through the Global Risks Perception Survey.

https://doi.org/10.1016/j.tre.2018.04.014
Received 25 April 2017; Received in revised form 16 February 2018; Accepted 30 April 2018

As an example, after Japan's earthquake occurrence in March 2011, most of the automobile plants stopped production. It was perceived that Nissan (an automobile manufacturer) would lose more in comparison with its competitors. But in reality, what happened was different since Nissan's recovery was remarkably better than the competitors. The remarkable point was that although Nissan is affected as much as its competitors, it also benefited from this calamity by increasing production by 9.3% towards the end of 2011 (Schmidt and Simchi-Levi, 2013). Hendricks and Singhal (2005a) claimed that after a disruption, the most harm arises from market share lost to the competitors, and not directly from damages to the SC's facilities. Therefore, the main question to ask is how the competitors and rivals will react to each SC's component after a disruption? Naturally, the rivals try to capture the lost market share of the SC. To reduce the lost market share of the SC by disruptions, SCs and the organizations' managers should ensure that the SCs are resilient enough to withstand failure and disruptions. They should consider that even small disorders in any component of SC could result in irreparable harm to the whole of the chain. Accordingly, considering the disruption risks in the planning of the SCs enhances competitiveness, reliability, service level, and reduces the unexpected costs arising from disruption time too.

Many types of SCND modeling efforts that consider the disruption risks and competitive supply chain network design (CSCND) have been developed in recent decades, but only few research consider the presence of both competition and disruption (Farahani et al., 2014). It should be considered that SCs compete with each other for obtaining greater market shares, although the SCs' components could compete to gain more profit too. A serious factor which could affect the competition among SCs or between the components of SC is disruptions and the way that the SCs are tackling disruptions. Therefore, this paper highlights the importance of both, competition and disruption in a SCND model, simultaneously. In other words, the simultaneous consideration of competition and disruption in a SC is one of the main contributions of this study, which currently scarcely exists in the literature. The aim of this research is to redesign a competitive SC network under operational risks and contingent disruptions, by utilizing bi-level and multi-objective programming approach. The competition is considered to be between the main producer company and its resellers (representatives). The elements that have been considered in modeling the problem include the three main competitive factors of service level, price, and distance as well as the demand uncertainty and the disruption at distribution centers (DCs) and connection links under the different scenarios.

2. Literature review

In this section, the most recent studies in CSCND and SCND under operational and disruption risks (as the main concept of the proposed model) are reviewed. Also, the exact solution approach for solving mixed integer bi-level (MIBL) model are reviewed briefly to clarify the merits of the proposed solution approach as compared with the available others in the literature. The recent review of related studies in CSCND (Farahani et al., 2014) is suggested for the interested reader.

2.1. A review on CSCND

The competitive factors that are affected by competition in all its forms (static, dynamic, and competition with foresight) have a great impact on the structure of the SCs (e.g. strategic, operational, and tactical decisions in SCs). Moreover, competitive factors influence the behavior of customers and the competitiveness of SCs (Farahani et al., 2014). In the literature regarding the competition in SCs, different characteristics are considered. The three main factors are the price of retailers (see Zhang, 2006; Nagurney et al., 2007; Rezapour et al., 2015b; Liu et al., 2016; Li et al., 2016; Konur and Geunes, 2016), nearest distance of customers to facilities (see Plastria and Vanhaverbeke, 2008; Aboolian et al., 2009; Kress and Pesch, 2012; Drezner et al., 2015; Redondo et al., 2015; Karakitsiou and Migdalas, 2015; Buechel and Roehl, 2015), and the service level (see Bernstein and Federgruen, 2004b, 2004a; Panda et al., 2013; Feng et al., 2013; Wen et al., 2016). In the literature, service-level is defined by different concepts (Farahani et al., 2014), but in our study, service level is defined as the percentage of satisfied demand using in-hand inventory without any delay. Considering the price, distance, and service-level could influence the strategic and operational decisions in CSCND. These three factors are rarely considered simultaneously, however a few studies such as Fernández et al. (2007) and Rezapour et al. (2014) considered both the price and distance. In addition, Anderson and Bao (2010), Rezapour and Farahani (2010), and Rezapour and Farahani (2014) considered both the service-level and price as important competitive factors.

The literature upon exploring, indicates that the competition in a SC is divided into three main categories: (1) competition among the beneficiaries in the same echelon of the SC (Nagurney and Toyasaki, 2005; Nagurney, 2006, 2010; Qiang, 2015); (2) competition among the beneficiaries in different echelons of the SC (Qiang, 2015; Narayanan et al., 2005) and; (3) competition between beneficiaries in different SCs (Majumder and Srinivasan, 2008; Rezapour et al., 2011, 2014, 2015b). In the first two categories related to the competition among the components of a single SC, most of the researchers dedicate their studies to SC planning, especially with the movement of materials, while the decisions related to number, capacity, and location of facilities have been ignored. However, these strategic decisions have an important effect on the competitiveness of a SC and could increase the gained profit by each rival in the SC. In addition, integrating the strategic and operational decisions improve the chain efficiency and effectiveness (Fallah et al., 2015). It can be observed that in recent years, a few studies consider both, intra SC competition in different echelons and strategic decisions, simultaneously. The one general reason could be the difficulty of solving the CSCND models.

2.2. Disruption and uncertainty considerations in SCND

The most recent review papers in the context of SC risks and resilient SCND are by Fahimnia et al. (2015b) that provide a classified review on the concept of SC risks and another by Tukamuhabwa et al. (2015), which provide a comprehensive review of the