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Supply chain network design under uncertainty: A comprehensive review and future research directions

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ABSTRACT

Supply chain network design (SCND) is one of the most crucial planning problems in supply chain management (SCM). Nowadays, design decisions should be viable enough to function well under complex and uncertain business environments for many years or decades. Therefore, it is essential to make these decisions in the presence of uncertainty, as over the last two decades, a large number of relevant publications have emphasized its importance. The aim of this paper is to provide a comprehensive review of studies in the fields of SCND and reverse logistics network design under uncertainty. The paper is organized in two main parts to investigate the basic features of these studies. In the first part, planning decisions, network structure, paradigms and aspects related to SCM are discussed. In the second part, existing optimization techniques for dealing with uncertainty such as recourse-based stochastic programming, risk-averse stochastic programming, robust optimization, and fuzzy mathematical programming are explored in terms of mathematical modeling and solution approaches. Finally, the drawbacks and missing aspects of the related literature are highlighted and a list of potential issues for future research directions is recommended.

Contents

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1. Introduction

In the early 1980s, SCM was introduced in order to respond to fierce competition among companies (Oliver & Webber, 1982). Over time, a growing number of corporations realized the significance of integrating their operations into key supply chain (SC) processes instead of managing them separately, thus extending the SCM evolution (La Londe, 1997). As pointed out by Handfield and Nichols (1999), SCM is "The holistic management approach for integrating and coordinating the material, information and financial flows along a supply chain." In accordance with Simchi-Levi, Kaminsky, and Simchi-Levi (2004) and the Council of Supply Chain Management Professionals, Melo, Nickel, and Saldanha-Da-Gama (2009) also defined SCM to be "The process of planning, implementing and controlling the operations of the supply chain in an efficient way." Several issues, such as appearance of short-life products, fierce competitions in today's markets, increasing expectations and changing customers' preferences, the development of new technologies, and globalization have led business enterprises to make large investments in their SCs (Simchi-Levi et al., 2004).

A SC, a complex network of organizations and facilities which are mostly settled in a vast geographical area or even the globe, synchronizes a series of interrelated activities through the network (Christopher, 1999). The SC network is also referred to as the logistics network by Simchi-Levi et al. (2004), and Ghiani, Laporte, and Musmanno (2004) defines the SC as "a complex logistics system in which raw materials are converted into finished products and then distributed to final users (consumers or companies)." On the other hand, Hugos (2011) points out that some differences exist between logistics management and SCM. In essence, logistics management, as a portion of SCM, focuses on activities such as inventory management, distribution, and procurement that are usually made on the boundaries of a single organization, while SCM includes other activities such as marketing, customer service, and finance as well.

SCND, also called *strategic supply chain planning*, is a part of the planning process in SCM, which determines the infrastructure and physical structure of a SC. Over the last two decades, SCND has been considered as a suitable application for *facility location* (FL) models. Revelle, Eiselt, and Daskin (2008) characterized existing FL models into four main types: *continuous*, *network*, *analytic*, and *discrete*. In spite of many differences among these models, they all include a set of customers with known locations and a set of facilities whose locations should be specified. Most SCND models belong to the category of discrete location models (Melo et al., 2009).

Several review papers exist on FL models, (e.g., Daskin, 2011; Owen & Daskin, 1998) and some surveys focus particularly on discrete location models (e.g., Klose & Drexl, 2005; Mirchandani & Francis, 1990; Revelle et al., 2008). However, FL models in the context of SCM have been reviewed by only a few papers, including Daskin, Snyder, and Berger (2005), Shen (2007b), and Melo et al. (2009). Therefore, there is still ample room to survey SCND models and methods.

Large investments are usually required to make strategic decisions in SCND. These decisions are very difficult to change and have long-term effects on SC's performance. The most common strategic decisions consist of determining locations and number of facilities, capacities and sizes of facilities, technology and area allocation for production and process of products at different facilities, selection of suppliers, and so on (Simchi-Levi et al., 2004). Over time (generally between three and five years), when a company has been influenced by these decisions, many parameters, including demand, capacity, and costs of its SC network, can have major fluctuations. Further, the parameters associated with SCND involve an enormous volume of data, often resulting in wrong estimations due to inaccurate forecasts and/or poor measurements in the modeling process (e.g., aggregation of demand points and products). Thus, SCND under uncertainty has obtained significant attention in both practice and academia over recent years.

Designing *reverse logistics* (RL) networks is another type of optimization problem based on the FL models. The RL networks are often designed for the purpose of collecting used, refurbished, or defective products from customers and then carrying out some recovery activities. Due to the stringent pressures from environmental regulations, many companies have been confronted with the challenge of designing RL networks. Locating facilities to perform recovery activities is one of the key strategic decisions to be made in this problem. Indeed, these facilities should operate properly over many years under uncertain business environments. Thus, the task of dealing with existing uncertainty in the return quantities and other parameters of RL networks plays a significant role in designing them. RL network design under uncertainty has attracted a great deal of attention and, as a result, an investigation into this problem is included in our review paper as well. It is noteworthy that this problem has many similarities to the SCND in terms of optimization approaches. Further, the forward and reverse logistics networks are often integrated, also known as closed-loop supply chain (CLSC) network.