Transportation Research Part E 81 (2015) 169–202

Contents lists available at ScienceDirect

Transportation Research Part E

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

Dynamic supply chain network design with capacity planning and multi-period pricing ☆

Mohammad Fattahi [a,b], Masoud Mahootchi [a], Kannan Govindan [b,*], Seyed Mohammad Moattar Husseini [a]

[a] Department of Industrial Engineering and Management Systems, Amirkabir University of Technology, Tehran, Iran
[b] Department of Business and Economics, University of Southern Denmark, Campusvej 55, Odense, Denmark

ARTICLE INFO

Article history:
Received 12 February 2015
Received in revised form 10 June 2015
Accepted 11 June 2015
Available online 24 July 2015

Keywords:
Dynamic supply chain network design
Capacity planning
Multi-period pricing approach
Simulated annealing
Linear relaxation-based heuristics

ABSTRACT

This paper addresses a new problem in designing and planning a multi-echelon and multi-product supply chain network over a multi-period horizon in which customer zones have price-sensitive demands. Based on price-demand relationships, a generic method is presented to obtain price levels for products and then, a mixed-integer linear programming model is developed. Due to the problem intractability, a simulated annealing algorithm that uses some developed linear relaxation-based heuristics for capacity planning and pricing is presented. Numerical results demonstrate the significance of the model as well as the efficiency of the solution algorithm and linear relaxation-based heuristics.

1. Introduction

Supply chain network design (SCND) is one of the principal components of the planning process in supply chain management. It usually encompasses several supply chain decisions with different planning levels to reach to a global and integrated system. Depending on their time horizons, planning levels in the supply chain can be strategic, tactical, and operational. In the last decade, several studies have addressed integrated tactical and strategic planning in SCND.

Regarding today's business environment, revenue management issues have emerged as a new dimension in supply chain planning. Revenue management can address two main categories of tactical decisions: price decisions and quantity decisions. As it is mentioned by Talluri and Van Ryzin (2006), price decisions determine how to set prices for different products and how to change prices of the products over the planning horizon. Quantity decisions determine how to allocate available capacities to different products at each time and when to withhold products from the customers in warehouses and sale them later. Embedding price and quantity decisions as two main tactical decisions into SCND leads to a challenging problem. Melo et al. (2009) have presented a comprehensive review on SCND studies and have introduced revenue management issues as possible future research directions.

Prices are critical decisions playing two main roles in supply chains: they determine the revenue for per unit of each product, and through a price-demand relationship for each product and each customer zone, they could change the required supply chain facilities and their capacities for demand fulfillment. There are little works, Ahmadi-Javid and Hoseinpour

☆ The paper is equally contributed and the authors' order is based on the requirement of the first author's PhD program.

* Corresponding author. Tel.: +45 65503188.
E-mail address: gov@sam.sdu.dk (K. Govindan).

http://dx.doi.org/10.1016/j.tre.2015.06.007
1366-5545/

(2015), Ahmadi-Javid and Ghandali (2014), Wagner and Falkson (1975), Hanjoul et al. (1990) and Hansen et al. (1997), to address profit maximization facility location problems where customer's demand is price-sensitive. In these works, location decisions are made in a single period for a single layer of a considerably simplified network. In addition, they assumed that price and location decisions belong to the same planning level and remain unchanged. These assumptions are not applicable for real supply chains and the intention of this paper is to consider price decisions in a comprehensive model for SCND that capture simultaneously many aspects relevant to real-life problems.

In today's competitive, complex, and dynamic business environment, many parameters such as supply and potential market demand can change. Nevertheless, in some cases such as encountering volatile market conditions, having capital limitations for large investments, or taking expansion opportunities into account, it may be essential to consider the possibility of making future adjustments in the supply chain structure. Therefore, in recent few years, SCND problems with multiple periods (see Correia et al., 2013; Badri et al., 2013; Melo et al., 2012; Melo et al., 2014; Wilhelm et al., 2013) have been more attractive. These are called dynamic SCND problems that generally consider possible adjustments in the location and/or capacity of supply chain facilities (Melo et al., 2009). In this paper, both strategic and tactical decisions are considered in a dynamic SCND problem with price-sensitive demands. To incorporate these two different types of planning decisions in the problem, two interconnected time intervals, including tactical and strategic periods are assumed in the planning horizon. Moreover, price decisions for multiple products are dynamically determined at each tactical period in an integrated optimization problem with the objective of maximizing supply chain net income.

One of the most important issues in dynamic SCND problems is capacity expansion planning in the network. Melo et al. (2006) investigated different approaches related to this issue in dynamic facility location problems. Moreover, many studies such as Aghezzaf (2005), Thanh et al. (2008), Badri et al. (2013) and Correia et al. (2013) have addressed the possibility of capacity expansion over a time horizon in their mathematical models. In the related literature, the manufacturing processes of products are not considered in presented capacity planning approaches. To address it, finite sets of capacity options for manufacturing processes are considered in each production plant. In each strategic period, only one capacity option for each process can be chosen. This capacity planning approach enables us to model various practical situations in which multi-product production should be performed through different manufacturing processes.

In recent years, several studies have addressed SCND problems, with emphasis on one or several but not all the features that we have considered in this paper. Furthermore, a few researchers (see Thanh et al., 2010; Melo et al., 2012; Melo et al., 2014; Badri et al., 2013) have attempted to present solution approaches for comprehensive problems in this area. However, a dynamic SCND problem with price-sensitive customers would be more complex and hence, the possible solution approaches in the literature are not applicable for the problem. The contributions of this paper are summarized as follows:

- A new dynamic SCND problem is addressed in which customer zones' demands are dependent on price decisions. This paper considers two interconnected tactical and strategic periods over a planning horizon to integrate location, capacity and price decisions.
- In the supply chain network, multiple products should be produced through different manufacturing processes at production plants and capacity expansion for the processes is possible over the planning horizon.
- In accordance to price-demand relationships of customer zones, a generic method is presented to obtain price levels for the products and then, a mixed-integer linear programming (MILP) model is proposed for the problem.
- An efficient solution approach is developed to solve such a dynamic SCND problem. In the solution approach, SA as a meta-heuristic approach is combined with several developed linear relaxation-based heuristics. These heuristics are presented based on the exploration of the MILP model structure to determine pricing and capacity decisions.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature related to this research study. Section 3 defines the problem characteristics and presents the MILP model. The meta-heuristic approach combined with efficient heuristics for solving the problem is explained in Section 4. Section 5 demonstrates the efficiency of the solution approach and computational results. Finally, Section 6 concludes the paper and offers guidelines for further research.

2. Related literature

This section is presented in two sub-sections. In the first sub-section, dynamic SCND problems are reviewed and in order to recognize their differences, we highlighted their four main features including: *(i) Supply chain network structure*; *(ii) Supply chain decisions and objective*; *(iii) Relevant aspects of dynamic SCND*; and *(iv) Solution approach for solving SCND problem*. In the second subsection, we discuss SCND problems in which price and location decisions should be made simultaneously.

2.1. Dynamic SCND

Surveys on facility location problems with a complete discussion about location problems in a multi-period context are provided by Daskin et al. (2005) and Klose and Drexl (2005). Among different types of facility location models, SCND is categorized under discrete location models. Melo et al. (2009) have presented a comprehensive review on different research studies in this area. It is worth noting that dynamic (i.e. multi-period) SCND problems are addressed by fewer researchers