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Stochastic Logistics Network Design with Deadlines

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INTRODUCTION

In this chapter, we consider a capacitated supply and distribution network design and planning problem in which customers' delivery deadlines and stochastic demand are to be satisfied in a make-to-order supply chain. In this supply chain, a set of contracted material suppliers ship semi-finished products to a group of processing centers for their assembly and final configuration. The finished products are then transported to a number of different demand points, each of which has an order quantity and a receiving deadline. Any shipment arrival after the deadline is penalized, and partial delivery (i.e., partial fulfillment of any order) is considered unacceptable The problem is to locate a set of processing centers that need to be opened and to determine the subset of demand points to processing centers and the corresponding supplier selection, so as to optimally minimize the total shipping and penalty costs due to unfilled customer orders, subject to the network capacity and deadline constraints. In this paper, we formulate the network design problem as a stochastic mixed integer nonlinear program with probability constraints and then prove that this problem is NP-hard, in the strong sense. We present an efficient algorithm for solving the design problem and perform empirical experiment to test the performance of the proposed algorithm.

BACKGROUND

Motivation

The study was motivated by the supply chain practices of the furniture industry (e.g., IKEA). In the furniture industry, companies purchase wood, veneers and components from contracted material suppliers overseas and then use direct containers or specialized pallets to ship these materials back to processing centers in North America where furniture is manufactured for wholesalers, or retailers to sell to customers in regional markets. Prior to the delivery to demand points, wood and semi-finished wood panels must be cut, glued, sized, sanded, assembled, labeled and packaged at the processing centers (PCs) according to customer specific requirements. The domestic trucks or rails are typically used to transport the finished goods from PCs to different regional markets. In regional markets there are many wholesalers and retailers who request the order quantity, a variety of products, and a delivery due date. It is understandable that customers expect wide selection, products that can be treated or customized on demand, and certainly fast, accurate delivery. The challenge facing furniture companies is providing this level of service cost effectively. Furniture manufacturers not only need to decide on the appropriate number of PCs to be opened, but

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the optimal assignment of demand points to PCs in order to achieve the best service at minimum cost. The delay in the delivery could lead to lost goodwill and customer dissatisfaction.

We consider a three-stage capacitated supply and distribution network. This network consists of a set of contracted material suppliers, a group of PCs, and many demand points in regional markets. Raw materials, components or semi-finished product needs to be shipped from lumber suppliers to PCs for their customization and final configuration. Then, each demand point receives the order shipped from the PC to which it is assigned. Each material-supplier has a limited production capacity and charges a shipping cost (via chartered vessels) proportional to the shipped quantities. Each PC has a limited processing capacity, processing time per unit, and holding cost. PCs start processing only after all the shipments from assigned material suppliers are received. Each demand point has uncertain demand, receives customized final furniture products from no more than one PC, and requests a due date. If the shipment cannot arrive at a demand point at the specified due date (due to the delay in shipping and/or the limitation of network capacity), a penalty cost proportional to the order size placed by that demand point is imposed. No partial delivery is acceptable. That is, if a demand point receives the furniture, then the order must be fully fulfilled. Both the shipping rate and the transit time between locations on the network are given. The objective is to determine the number of PCs to be opened, and the assignment of the demand points to PCs such that the total shipping and penalty cost is minimized.

Literature Review

Supply chain network design problem involves selecting new sites from a finite set of available candidate locations to be open and has been widely investigated in the supply chain management (Sridharan, 1995; Daskin, 1995; Owen & Daskin, 1998; Revelle & Eiselt, 2005; Melo et al., 2009). Lee and Moon et al (2010) studied a supply chain network design problem with some practical applications and proposed two mixed integer programming models, one without routing and one with routing. In addition, they developed a LP-relaxation based heuristic algorithm to determine the optimal location, allocation, and routing while minimizing the total cost to the supply chain network. Yadav and Mishra et al. (2011) dealt with the selection of the optimal combination among the different conflicting criteria while making a trade-off between the supply chain cost, sales profit and the product design complexities. Goetschalckx and Huang et al. (2012) considered a comprehensive and integrated model of the structure and the behavior of a manufacturing enterprise supply network. This model captured the inherent uncertainty of the future environmental conditions in which the supply network will have to function. The supply network risk was handled through the variability in the profits of the supply network for the various scenarios. Creazza and Dallari et al. (2012) proposed an integrated model for designing and optimizing international logistics networks. This model contained a mixed integer linear programming model and a data-mapping section to solve the configuration problem for supply chains characterized by a complexity level, which typically occurs in real-life global logistics networks. Longinidis et al. (2013) introduced financial performance and credit solvency modeling to SCN design with economic uncertainty. They proposed a multi-objective mixed integer non-linear programming problem, and used a real case study to show that the model is applicable and is utilized as effective strategic decision tool.

Most of supply chain network design problems involved with lead times focused on the operational/tactical management decisions such as inventory management (Graves & Willems, 2003; Levi & Zhao, 2005; Kaminsky & Kaya, 2008), supplier-buyer relationship (Barnes-Schuster et al., 2006; Jha & shanker, 2009) and management and planning of production/distribution systems (Spitter et al., 2005; Barnes-Schuster et al., 2006). However, Hammami and Frein (2013) dealt with