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A fuzzy linear programming model for the optimization of multi-stage supply chain networks with triangular and trapezoidal membership functions

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Abstract

Supply chain management (SCM) is concerned with a complex business relations network that contains interrelationships between various entities, such as suppliers, manufacturers, distribution centers and customers. SCM integrates these entities and manages their interrelationships through the use of information technology to meet customer expectations (i.e., higher product variety and quality, lower costs and faster responses) effectively along the entire value chain. Thus, one of the vital issues in supply chain management is the design of the value chain network. In this paper, a fuzzy linear programming model for the optimization of the multi-stage supply chain model with triangular and trapezoidal membership functions is presented. The model determines the fuzzy capacities of the facilities (plants or distribution centers (DCs)) and the design of the network configuration with a minimum total cost. The total cost involves the shipping cost from suppliers; transportation costs between plants and DCs; distribution costs between DCs and customer zones; and opportunity costs from not having the material at the right time. The developed model is solved by a professional software package (LINDO), and the computational results are discussed.

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1. Introduction

In the current age of globalization, enterprises struggle against their competitors and survive by cooperating with their strategic partners. These cooperative or collective efforts evolve a new type of relationship, the supply chain relationship, among these companies, and furthermore, they foster a new concept in management: the supply chain management (SCM) [9,7,4,3,12,8,19,6]. In the last several years, many studies have been proposed and much research has been performed on the design and optimization of supply chain networks. In one study, Pirkul and Jayaraman [21] studied a multi-commodity, multi-plant, capacitated facility location problem and proposed an efficient heuristic solution to the problem. In the capacitated plant and warehouse location model, customers typically demand multiple units of different products that are distributed to customer outlets from open warehouses that receive these products from several manufacturing plants. The objective function of the model minimizes the sum of the fixed cost of establishing and operating the plants and the warehouses plus the variable cost of transporting units of products from the plants to the warehouses and distributing the products from the warehouses to the customer, to satisfy the multiple demands of the customers.

Timpe and Kallrath [26] considered a multi-site, multi-product production network and presented a general mixed integer linear programming model that combines aspects related to production, distribution and marketing and involves production sites (plants) and sales points. Lakhal et al. [17] proposed a mathematical programming model of an extended enterprise, which can be used to investigate strategic networking. A number of general network modeling constructs are proposed. A model to optimize the supply chain structure under specific assumptions on the nature of the production, cost and value functions in typical production/distribution companies is then derived. A heuristic to obtain solutions from the model is also presented. Finally, an example based on a refrigerator company is used to illustrate the usefulness of the approach. Cakravastia et al. [5] developed an analytical model of the supplier selection process in designing a supply chain network. The constraints on the capacity of each potential supplier are considered in the process. The objective of the supply chain is to minimize the level of customer dissatisfaction, which is evaluated by two performance criteria: (i) price and (ii) delivery lead time. The overall model operates at two levels of decision-making: the operational level and the chain level. The operational level concerns decisions related to optimizing the manufacturing and logistical activities of each potential supplier, to meet the customer's requirements. At the chain level, all of the bids from potential suppliers are evaluated, and the final configuration of the supply chain is determined. The structure of the chain depends on the product specifications and on the customer's order size. An optimal solution in terms of the models for the two levels can be obtained using a mixed-integer programming technique [5,25] presented a multi-phase mathematical programming approach for effective supply chain design. More specifically, the methodology develops and applies a combination of multi-criteria efficiency models based on game theory concepts and linear and integer programming methods. Korpela et al. [15] proposed a framework with which the risks were related to a customer–supplier relationship; the service requirements by the customers and the strategies of the supplier company can be included in the production capacity allocation and the supply chain design. Essentially, the target is to prepare a sales plan where the limited production capacity is allocated to the customers based on their strategic importance and the risk involved. Furthermore, the supply chain is designed on