Information Sciences 268 (2014) 185–201

Contents lists available at ScienceDirect

Information Sciences

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

Combining possibilistic linear programming and fuzzy AHP for solving the multi-objective capacitated multi-facility location problem

Dogan Ozgen *, Bahadir Gulsun

Department of Industrial Engineering, Mechanical Faculty, Yildiz Technical University, 34349 Istanbul, Turkey

ARTICLE INFO

Article history:
Received 12 May 2009
Received in revised form 26 December 2013
Accepted 15 January 2014
Available online 24 January 2014

Keywords:
Possibilistic linear programming
Fuzzy AHP
Supply chain network design
Capacitated multi-facility location problem
Multi-objective programming

ABSTRACT

The capacitated multi-facility location problem is a complex and imprecise decision-making problem which contains both quantitative and qualitative factors. In the literature, many objectives for optimizing many types of logistics networks are described: (i) minimization objectives such as cost, inventory, transportation time, environmental impact, financial risk and (ii) maximization objectives such as profit, customer satisfaction, and flexibility and robustness. However, only a few papers have considered quantitative and qualitative factors together with imprecise methodologies. Unlike traditional cost-based optimization techniques, the approach proposed here evaluates these factors together while considering various viewpoints. Decision-makers must deal both factors together to model complex structure of real-world applications. In this paper, a two-phase possibilistic linear programming approach and a fuzzy analytical hierarchical process approach have been combined to optimize two objective functions ("minimum cost" and "maximum qualitative factors benefit") in a four-stage (suppliers, plants, distribution centers, customers) supply chain network in the presence of vagueness. The results and findings of this method are illustrated with a numerical example, and the advantages of this methodology are discussed in the conclusion.

1. Introduction

Today's global market competition and high customer expectations have forced enterprises to consider their supply chains (SC) more carefully. Supply chain decisions are important strategic decisions which affect every member of the chain because the various functions performed by these members are integrated with each other. Among these functions are marketing, distribution, planning, manufacturing, and purchasing.

The capacitated multi-facility location and SC network design problem is one of the most comprehensive strategic decision problems that need to be optimized for long-term efficient operation of the whole supply chain. This problem determines the number, location, capacity, and type of the plants, warehouses, and distribution centers to be used. It also establishes distribution channels and the quantities of materials and items to consume, produce, and ship from suppliers to customers [1].

Location-allocation decisions involve substantial capital investment and result in long-term constraints on the production and distribution of goods. These problems are complex and, like most real-world problems, depend on a number of tangible

* Corresponding author. Tel.: +90 212 383 2918.
E-mail address: doganozgen@gmail.com (D. Ozgen).

http://dx.doi.org/10.1016/j.ins.2014.01.024
0020-0255/

and intangible factors which are unique to each problem. The complexity of these systems arises from a multitude of quantitative and qualitative factors which influence location choices as well as from the intrinsic difficulty of making numerous tradeoffs among those factors [5]. Over and above this complexity, global SC management is difficult because multiple sources of uncertainty and complex interrelationships at various levels between diverse entities exist in the SC, and therefore it is very difficult to determine simultaneously the supply chain configuration and the SC total cost. Fast-changing transportation and facilities costs, facility capacities, and customer demands are some of the SC parameters which are difficult to predict accurately because of imprecision in the environment.

Supply chain network (SCN) design problems reviewed in the literature have been examined for situations ranging from a single product type to complex multi-product systems; the models developed range from linear deterministic models to complex nonlinear stochastic ones. The number of objective functions also depends on the degree of complexity of the problem. Generally, these problems involve multiple and conflicting objectives such as cost, service level, and resource utilization. To deal with multiple objectives and to enable the decision-maker to evaluate a greater number of alternative solutions, various numbers of supply chain levels or stages and various solution approaches and methodologies have been used. Supply chain network design levels are determined according to the components of the supply chain network problem being considered. In this research, papers in the literature have been categorized based on the number of SCN levels. The criteria considered in the objective functions and the solution methods and methodologies used in the literature are also reviewed.

Vercellis [40] presented a capacitated master production planning and capacity allocation problem for a multi-plant manufacturing system with two serial stages in each plant. The objective of the problem is to minimize the sum of the various cost factors, namely the production cost in stages 1 and 2, inventory, lost demand, transportation, and overtime. The resulting mixed $\{0,1\}$ linear programming model is solved by means of LP-based heuristic algorithms.

Zhou and Liu [47] proposed a mathematical model and an efficient solution procedure for a bi-criteria allocation problem involving multiple warehouses with different capacities. They also considered two conflicting objectives, transit time and shipping cost, with respect to the warehouse allocation problem. Their proposed solution procedure used a genetic algorithm that is designed to find Pareto optimal solutions for this problem in a short period of time. Romeijn et al. [32] considered a traditional deterministic single-DC multi-retailer (SDMR) model. They tried to minimize the location and transportation costs and the two-level inventory costs. An additional cost term that represents costs related to safety stocks or capacity issues was also proposed. They formulated the problem as a set covering model.

Cakravastia et al. [9] aimed to develop an analytical model for the supplier selection process when designing a supply chain network. The assumed 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. An optimal solution in terms of the models for the two levels can be obtained using a mixed-integer programming technique. Syam [36] extended traditional facility location models by introducing several logistical cost components such as holding, ordering, and transportation costs in a multi-commodity, multi-location framework. Their paper provided an integrated model and sought to minimize total physical distribution costs by simultaneously determining optimal locations, flows, shipment compositions, and shipment cycle times. Two sophisticated heuristic methodologies, based on Lagrangean relaxation and simulated annealing respectively, were provided and compared in an extensive computational experiment. Yan et al. [43] proposed a strategic production–distribution model for supply chain design with consideration of bills of materials (BOM). Logical constraints were used to represent BOM and the associated relationships among the main entities of a supply chain such as suppliers, producers, and distribution centers. Moreover, these relationships were formulated as logical constraints in a mixed integer programming (MIP) model, thus capturing the role of BOM in supplier selection in the strategic design of a supply chain. The total cost of the supply chain included purchasing cost, production cost, transportation and distribution cost, and fixed costs such as the fixed ordering cost, the fixed cost to open and operate a producer, and the fixed cost to open and operate a DC. Chen and Lee [11] proposed a multi-product, multi-stage, and multi-period scheduling model to deal with multiple incommensurable goals for a multi-echelon supply chain network with uncertain market demands and product prices. The supply chain scheduling model is constructed as a mixed integer nonlinear programming problem to satisfy several conflicting objectives, including fair profit distribution among all participants, safe inventory levels, maximum customer service levels, and robustness of decisions to uncertain product demands. For the solution, a two-phase fuzzy decision-making method was presented.

Amiri [3] developed a mixed integer programming model and presented a Lagrangean-based solution procedure for the problem. The model minimizes total costs, including the costs to serve the demands of customers from the warehouses, the costs of shipments from the plants to the warehouses, and the costs associated with opening and operating the warehouses and the plants. Yilmaz and Çatay [44] addressed a strategic planning problem for a three-stage production–distribution network. The problem consisted of a single-item, multi-supplier, multi-producer, and multi-distributor production–distribution network with deterministic demand. The objective was to minimize the costs associated with production, transportation, and inventory as well as capacity expansion costs over a given time horizon. The problem was formulated as a 0–1 mixed integer programming model. Efficient relaxation-based heuristics were considered to obtain a good feasible solution. Tsiakis and Papageorgiou [39] proposed a mixed integer linear programming (MILP) model to assist senior operations management in making decisions about production allocation, production capacity per site, purchase of raw materials, and network configuration, while taking into account financial aspects (exchange rates, duties, etc.) and costs. The objective function included fixed infrastructure costs, production costs, material-handling costs at distribution centers, transportation costs, and duties.