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A class of multi-objective supply chain networks optimal model under random fuzzy environment and its application to the industry of Chinese liquor

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Abstract

An important issue, when shipping cost and customers demand are random fuzzy variables in supply chain network (SCN) design problem, is to find the network strategy that can simultaneously achieve the objectives of minimization total cost comprised of fixed costs of plants and distribution centers (DCs), inbound and outbound distribution costs, and maximization customer services that can be rendered to customers in terms of acceptable delivery time. In this paper, we propose a random fuzzy multi-objective mixed-integer non-linear programming model for the SCN design problem of Luzhou Co., Ltd. which is representative in the industry of Chinese liquor. By the expected value operator and chance constraint operator, the model has been transformed into a deterministic multi-objective mixed-integer non-linear programming model. Then, we use spanning tree-based genetic algorithms (st-GA) by the Prüfer number representation to find the SCN to satisfy the demand imposed by customers with minimum total cost and maximum customer services for multi-objective SCN design problem of this company under condition of random fuzzy customers demand and transportation cost between facilities. Furthermore, the efficacy and the efficiency of this method are demonstrated by the comparison between its numerical experiment results and those of tradition matrix-based genetic algorithm.

Keywords: Multi-objective optimization; Supply chain networks; Random fuzzy variable; Prüfer number; Genetic algorithm

1. Introduction

In recent years, the supply chain network (SCN) design problem has been gaining importance due to increasing competitiveness introduced by the market globalization. A supply chain, beginning with the production of raw material by a supplier and ending with the consumption of a product by the customer, is a set of suppliers, facilities, products, customers and of controlling inventory, purchasing, and distribution. Traditionally, marketing, distribution, planning, manufacturing, and purchasing organizations along the supply chain are operated independently. These organizations have their own objectives and these objectives are often

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conflicting. But, there is a need for a mechanism through which these different functions can be integrated together [2]. Supply chain management (SCM), which appeared in the early 1990s and involved planning and managing production/manufacturing, transportation and distribution, offers a strategy through which such integration can be achieved and a way to improve industrial environment [39].

SCN design problems cover a wide range of formulations ranged from simple single-product type to complex multi-product type, and from linear deterministic models to complex non-linear uncertain models. The network design problem is one of the most comprehensive strategic decision problems that need to be optimized for long-term efficient operation of whole supply chain. It determines the number, location, capacity and type of plants, warehouses, and distribution centers (DCs) to be used. It also establishes distribution channels, and the amount of materials and items to consume, produce, and ship from suppliers to customers. In literatures, there are different studies tackling the design problem of supply networks and these studies have been surveyed by Vidal and Goetschalckx [45], Beamon [5], Erengüc et al. [14], Shen [40], Ko et al. [24] and Romeijn et al. [37]. However, the majority of this research assumes that the operational characteristics of and the design parameters of the supply chain are deterministic. Unfortunately, real-world situation is often not deterministic, and some factors such as demands, allocations, cost of shipment, even locations of customers and facilities are usually changing, hence we must consider the supply chain network design problem under uncertain environment. A number of research on stochastic parameters involving distribution of raw materials and products and facility location of supply chain have been made in strategic level and tactical level [13,47]. Beginning with the seminal work of Geoffrion and Graves [18] on multi-commodity distribution system design, a large number of optimization-based approaches have been proposed for the design of supply chain networks [4,9]. While reviewing the literatures, we find that there are three methods of solving the uncertainty problem of supply chain design network: Benders decomposition algorithm, branch-and-fix heuristic, and hybrid approach. MirHassani et al. [34], Tsiakis et al. [44], Choudhary et al. [10] and Santoso et al. [38] proposed the Benders decomposition algorithm (or modification of the Benders decomposition algorithm) which commonly used for deterministic network design problems to generate robust designs, and they created network configurations that are good (nearly optimal) for a variety of scenarios of the design parameters. Alonso-Ayuso and Escudero et al. [1] proposed approach of branch-and-fix heuristic for solving two-stage stochastic supply chain computational results on networks involving 6 plants, 12 products, 24 markets, and 23 scenarios were presented. Chan et al. [6], Chan and Chung [7], and Chen and Lee [8] developed a hybrid approach based on genetic algorithm and Analytic Hierarch Process (AHP) (or two-phase fuzzy decision-making method) for production and distribution problems in multi-factory, multi-product, multi-stage, and multi-period scheduling SCN with uncertain market demands and product prices. As to the fuzziness, since Zadeh's pioneering work [48], the fuzzy sets theory has been applied to different management problems. Many successful applications of the theory in the area of fuzzy optimization can be found in literature. Zimmermann [50], Chen and Lee [8], Amid et al. [3], Kulak and Kahraman [25] and Wang [46] proposed different methods to solve fuzzy multi-objective linear programming problems.

Unfortunately, the SCN design problem is subject to many sources of uncertainty besides random uncertainty and fuzzy uncertainty [21]. In a practical decision-making process, we often face a hybrid uncertain environment. To deal with this twofold uncertainty, fuzzy random variable was proposed by Kwakernaak [26,27] to depict the phenomena in which fuzziness and randomness appear simultaneously [15,36,20]. Several research works have been published in recent years [11,42,32]. However, in this paper, we consider the amount of demand on the products as normally distributed variable $\mathcal{N}(\mu, \sigma^2)$ from the view point of probability theory, and the values of μ as a triangular fuzzy variable (a, b, c) because of scanty data to analyze. Therefore, probability SCN with fuzzy parameters appears. In this case, random fuzzy variable which was presented by Liu [30] can be used to deal with this kind of combined uncertainty of randomness and fuzziness. How to model and solve the problem of supply chain network (SCN) design in random fuzzy environment is a new area of research interest. To the best of the author's knowledge, so far, there is little research in this area.

Our purpose in this paper is to make some contribution on SCN design in an uncertain environment of combined randomness and fuzziness and obtain optimal solutions. We apply uncertain programming techniques to the real SCN design problem, and provide optimal alternative solutions obtained by genetic algorithms to the decision-maker. The genetic algorithms (GA) which was introduced by Holland to tackle combinatorial problems is heuristic search techniques inspired from the principles of survival-of-the-fittest