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A class of chance constrained multiobjective linear programming with birandom coefficients and its application to vendors selection

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ABSTRACT

In this paper, a class of chance constrained multiobjective linear programming model with birandom coefficients is considered for vendor selection problem. Firstly we present a crisp equivalent model for a special case and give a traditional method for crisp model. Then, the technique of birandom simulation is applied to deal with general birandom objective functions and birandom constraints which are usually difficult to be converted into their crisp equivalents. Furthermore, a genetic algorithm based on birandom simulation is designed for solving a birandom multiobjective vendor selection problem. Finally, a real numbers example is given. The paper makes certain contribution in both theoretical and application research related to multiobjective chance constrained programming, as well as in the study of vendor selection problem under uncertain environment.

1. Introduction

Vendor selection (also called supplier selection) is a key process of supply chain management. The success of a supply chain is highly dependent on selection of good suppliers. The supplier selection problem has received considerable attention in academic research and literature. The first related papers can be traced back to the 1950s when applications of linear programming and scientific computations were at their beginning. The first recorded supplier selection model was used by the National Bureau of Standards in the United States of America to find the minimum cost way for awarding procurement contracts in the Department of Defense (Stanley et al., 1954; Gainen, 1955). The existent literature surveys focused on papers starting from the mid 1960s. The earliest review was by Moore and Fearon (1973) where they focused on industry applications of computer-assisted supplier selection models. Weber et al. (1991) annotated and classified 74 articles with regard to the particular criteria mentioned in the study, the purchasing environment and the decision technique used. A review by De Boer et al. (2001) discussed a framework for supplier selection. The authors recognized the prior steps leading to the theoretical solution and presented the main published works that deal with all the supplier selection process. Aissaoui et al. (2007) presented a most comprehensive literature review that covered the entire purchasing process, considered both parts and services outsourcing activities, and covered internet-based procurement environments such as electronic marketplaces auctions, finally analyzed and exposed the main decision's features, and proposed different classifications of the published models. Gheidar-Kheljani et al. (2009) considered the issue of coordination between one buyer and multiple potential suppliers, and made the total cost of the supply chain minimized rather than only the buyer's cost.

However, the majority of this research in the literature assumed the parameters to be deterministic. Characteristically, real-world situations are often not deterministic, and some factors such as demands, item price and allocations are usually changing, hence we must consider the vendor selection problem under uncertainty. Horowitz (1986) considered a two-source purchasing problem with one source's price uncertain. Kasilingam and Lee (1996) considered a normally distributed demand in a multiple item single period model. Bonser and Wu (2001) developed a stochastic program to model a multi-source fuel procurement for an electrical utilities firm considering both demand and price uncertainty. Yang et al. (2007) provided a newsvendor approach to decide ordering quantities from a set of vendors with random yields and prices while facing stochastic demand. Liao and Rittscher (2007) developed a comprehensive multiobjective supplier selection model under stochastic demand conditions considering demand quantity and timing uncertainties. Awasthi et al. (2009) considered a supplier selection problem for a single manufacturer/retailer who faced a random demand. Zhang and Zhang (2011) addressed the supplier selection and purchase problem with fixed selection cost and limitation on minimum and maximum order sizes under stochastic demand. Also, the

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vendor selection problem under fuzzy environment has been studied by some scholars. Kumar et al. (2004, 2006) developed a fuzzy goal programming and a fuzzy multiobjective integer programming approach to handle the vagueness and imprecision in vendor selection model. Amid et al. (2006) applied an asymmetric fuzzy-decision-making technique to assign different weights to various criteria in a fuzzy vendor selection problem, and formulated a weighted additive fuzzy multiobjective model for vendor selection problem under price breaks (Amid et al., 2009). Faez et al. (2009) introduced an integrated model based on the CBR method in a fuzzy environment and mathematical programming for a single item vendor selection problem. Wang et al. (2008) proposed a fuzzy vendor selection expected value model and a fuzzy vendor selection chance constrained programming model by characterizing quality, budget, and demand as fuzzy variables. Awasthi et al. (2010) presented a fuzzy multi-criteria approach which consisted of three steps for evaluating environmental performance of suppliers. Bai and Sarkis (2010) utilized gray system and rough set theory and integrated sustainability discussion into the supplier selection modeling.

However, in a practical decision-making process, we often face a hybrid uncertain environment where linguistic and frequent nature coexist. Several research works dealing with this twofold uncertainty have been published in recent years (Liu, 2004; Li et al., 2006; Xu et al., 2008; Xu and Yao, 2009). However, in this paper, the amount of demand on the items is normally distributed variable $\mathcal{N}(\mu,\sigma^2)$ from the view point of probability theory, and the values of μ is another random variable because of some stochastic data, therefore, twofold random parameters appear. In this case, birandom variable, which was presented by Peng and Liu (2007) can be used to deal with this kind of dual uncertainty. How to model and solve the problem of vendor selection in birandom environment is a new area of research interest. To the best of the authors knowledge, so far there is little research in this area.

In this paper, a birandom CCMOLP model is developed based on chance measure of birandom event (Peng and Liu, 2007; Liu, 2002) for the vendor selection problem. The rest of this paper is organized as follows. In Section 2, we state the vendor selection problem. Making some assumptions for this problem, based on recalling some definitions about birandom variables, a birandom chance constrained multiobjective model is proposed. Section 3 studies pr–pr constrained multiobjective programming model. We converted it into its crisp equivalent model for a special case. After discussed the convexity of the model, we give an interactive random satisfying method to obtain the decision maker's satisfactory solution. In Section 4, we apply the technique of birandom simulation to check the complex functions and develop a birandom simulation-based genetic algorithm. In Section 5, a VSP is given in order to show the application of the proposed model and algorithm. Finally concluding remarks are outlined in Section 6.

2. The vendor selection model with birandom coefficients

In this section of the paper, we propose a chance constrained multiobjective linear programming model for vendor selection problem under birandom environment.

2.1. The problem description

In a supply chain, the plants want to buy raw materials or other products from N different vendors and take a variety of vendor attributes such as quality, price and lead-time into consideration. Individual vendors have different performance characteristics due to different criteria. For example, the vendor who can supply an item for the least per unit price may not have the best quality performance of all the competing vendors. Therefore, the buyer must balance price, quality and lead-time when selecting vendors. The buyer will select a series of vendors and their quotas from a large number of potential vendors with the goal of minimizing total monetary cost, the total of rejected purchased items, total late delivery within the constraints of the demand and budget allocated to the vendors, and vendors supply abilities.

In this paper, we will consider the vendor selection problem under the following assumptions:

(1) Only one item is purchased from one vendor.
(2) Quantity discounts are not taken into consideration.
(3) No shortage of the item is allowed for any of the vendors.
(4) The problem happens in birandom environment, i.e., some parameters are birandom variables.

2.2. Birandom chance constrained multiobjective programming

To describe the twofold random parameters, some knowledge of birandom theory is introduced in this section. The definition of birandom variable and the results are cited from Peng and Liu (2007).

Definition 2.1. Let Ω be a nonempty set, $\mathcal{A}$ is a σ-algebra of subsets of Ω, Pr is a probability measure. Then the triplet $(\Omega,\mathcal{A},Pr)$ is called a probability space.

Definition 2.2. A birandom variable ξ is a mapping from a probability space $(\Omega,\mathcal{A},Pr)$ to a collection $\mathcal{S}$ of random variables such that for any Borel subset B of the real line $\Re$, the induced function $Pr\{\xi(\omega)\in B\}$ is a measurable function with respect to ω.

Definition 2.3. An n-dimensional birandom vector ξ is a mapping from the probability space $(\Omega,\mathcal{A},Pr)$ to a collection of n-dimensional random vector such that $Pr\{\xi(\omega)\in B\}$ is a measurable function with respect to ω for any Borel subset B of the real space $\mathcal{R}^n$.

Consider the following multiobjective programming problem with birandom coefficients

$$\begin{aligned}\max\quad & \{f_1(x,\xi),f_2(x,\xi),\ldots,f_m(x,\xi)\}\\ \text{s.t.}\quad & g_r(x,\xi)\le 0,\quad r=1,2,\ldots,p\end{aligned}\tag{1}$$

where x is an n-dimensional decision vector, $\xi=(\xi_1,\xi_2,\ldots,\xi_m)$ is a birandom vector, $f_i(x,\xi)$ are objective functions, $i=1, 2,\ldots,p$, describing the goals of vendor selection problem. Because of the birandom vector ξ, the problem (1) is not well defined. That is, the meaning of maximizing $f_i(x,\xi), i=1,2,\ldots,m$ is not clear and constraints $g_r(x,\xi)\le 0, r=1,2,\ldots,p$ cannot define a deterministic feasible set. To deal with the birandom events $g_r(x,\xi)\le 0, r=1,2,\ldots,p$, the primitive chance measure was introduced.

Definition 2.4. Let $\xi=(\xi_1,\xi_2,\ldots,\xi_n)$ be a birandom vector on $(\Omega,\mathcal{A},Pr)$, and $f:\mathcal{R}^n\to\mathcal{R}^m$ be a vector-valued Borel measurable function. Then the primitive chance of birandom event characterized by $f(\xi)\le 0$ is a function from (0,1] to [0,1], defined as

$$Ch\{f(\xi)\le 0\}(\alpha)=sup\{\beta|Pr\{\omega\in\Omega|Pr\{f(\xi(\omega))\le 0\}\ge\beta\}\ge\alpha\}\tag{2}$$

Chance constrained programming introduced by Charnes and Cooper (1959) is useful because it considers the decision maker's confidence level. Based on the definition of primitive chance, the maximax birandom chance constrained multiobjective programming (CCMOP) model was proposed as follows:

$$\begin{aligned}\max\quad & \{\bar{f}_1,\bar{f}_2,\ldots,\bar{f}_m\}\\ \text{s.t.}\quad & \begin{cases}Ch\{f_i(x,\xi)\ge\bar{f}_i\}(\gamma_i)\ge\delta_i, & i=1,2,\ldots,m\\ Ch\{g_r(x,\xi)\le 0\}(\eta_r)\ge\theta_r, & r=1,2,\ldots,p\end{cases}\end{aligned}\tag{3}$$