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Product mix problems considering several probabilistic conditions and flexibility of constraints

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Abstract

This paper considers product mix problems including randomness of future returns, ambiguity of coefficients and flexibility of upper value with respect to each constraint such as budget, human resource, time and several costs. Particularly, the flexibility is assumed to be a fuzzy goal. Then, several models based on maximizing total future profits under a level of satisfaction to each fuzzy goal are proposed. Furthermore, the model considering preference ranking to each fuzzy goal of constraints is proposed. Since these problems are basically formulated as nonlinear programming problems, the transformations into deterministic equivalent problems are introduced and the efficient solution methods are developed. A numerical example for product mix problem is given to illustrate our proposed models.
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Keywords: Product mix problems; Multi-objective fuzzy programming; Chance-constrained programming; Probability maximization model

1. Introduction

In many corporations and industries, there are many decision making problems such as scheduling problem, logistics, data mining and allocation problem. In asset allocation problems, it is important to predict future total returns and to decide an optimal asset allocation maximizing total profits or minimizing total costs under some constraints. Product mix problems and production planning problem included in asset allocation problems are also major problems of decision making in the manufacture, and these problems play an important role in the prediction of future return and economic strength of the firm. Until now, many researchers have considered minimizing the total costs derived from production processes of firms, and recently many mathematical models have been proposed (Letmathe & Balakrishnan, 2005; Li & Tirupati, 1997; Morgan & Daniels, 2001; Mula, Poler, Garcia-Sabater, & Lario, 2006b). However, minimizing the total cost does not mean maximizing the total future profit. Hence, decision makers need to consider not only minimizing the total costs but also maximizing the total profit, simultaneously. In order to accomplish both objects, they

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also consider what products, how many and when they produce. In addition to this, there are many probabilistic and ambiguous factors in the production processes; breakdown of machines, ability of employee, lack of efficient information, etc. Then, they may have a negative effect to produce the expected quantities a priori with respect to maximizing the total profit. Recently, some researchers have studied production planning problems including ambiguous situations (Mula, Poler, & Garcia, 2006a, 2007; Vasant, 2006). In our previous study (Hasuike, 2006), we have considered product mix problems under both randomness and fuzziness.

Furthermore, since manufacturing companies often face such high demand volatility, the companies would need to possess some degrees of flexibility in order to cope with these changes in the manufacturing environment and to stay competitive and profitable. Consequently, flexibility in manufacturing operations, particularly product-mix flexibility, is becoming more important for industrial firms in order to respond to changes in the environment; product life cycles are becoming shorter, increase of customer demand with respect to customization at prices for standard products, and markets are more global than ever. However, the flexibility has not been clearly defined. Since the seminal work by Browne, Dubois, Rathmill, Sethi, and Stecke (1984) in classifying and distinguishing between different flexibility types, many authors have provided different interpretations of flexibility types related to product-mix flexibility; Job flexibility (Buzacott, 1982), Product flexibility (Browne et al., 1984; Hyun & Ahn, 1992; Sethi & Sethi, 1990; Son & Park, 1987), Process flexibility (Sethi & Sethi, 1990) and Product-mix flexibility (Berry & Cooper, 1999; Gerwin, 1993; Grubbström & Olhager, 1997; Olhager, 1993).

On the other hand, there are many researches (Aryanezhad & Komijan, 2004; Balakrishnan & Cheng, 2000; Coman & Ronen, 2000; Finch & Luebbe, 2000; Köksal, 2004; Lee & Plenert, 1993; Luebbe & Finch, 1992; Souren, Ahn, & Schmitz, 2005) focused on bottle-neck constraints of production processes, called as theory of constraints (TOC) proposed by Goldratt (1990, 1993). Product-mix decision problems through TOC should take into account considerations like the aspiration level of decision-maker in order to make product-mix decision a robust one. In product-mix decision problems through TOC, several types of them are considered, and Bhattacharya and Vasant (2007) compile these product-mix decision problems through TOC. However, there are few models considering not only random and ambiguous situations but also flexibility and aspiration of objective function and constraints, simultaneously. Therefore, in this paper, we consider product mix problems to take several probabilistic and possibilistic constraints into account.

While, in asset allocation problems, product mix problems and portfolio selection problems focused on only budget constraint are considered as similar problems. Portfolio selection problems have been initialized by Markowitz (1952). He has combined probability and optimization theory to the investment behavior, and formulated portfolio selection problem mathematically as follows: (1) minimizing variance for a given expected value, and (2) maximizing expected value for a given variance. Portfolio theory has been greatly improved since Markowitz and recently there are some researches of portfolio selection problems under the randomness and fuzziness (Hasuike & Ishii, 2007a; Huang, 2007; Inuiguchi & Ramik, 2000; Katagiri, Sakawa, & Ishii, 2005).

In this paper, we extend these results and develop theories to product mix problems. Particularly, in the case that upper value of each constraint is not assumed to be the fixed value but variable including a measure of range, we have more flexible and more complicated situations. Therefore, in this paper, we introduce aspiration levels to each constraint and propose the following three models under several randomness, fuzziness and flexibility; (a) probability fractile optimization model to total future profits, (b) probability maximization model to total future profits, and (c) preference ranking model. These mathematical programming problems with probabilities and possibilities are usually transformed into deterministic equivalent nonlinear programming problems. Then we construct the efficient solution method to find the global optimal solution of corresponding nonlinear programming problems.

This paper is organized as follows; next section is about the formulation of product mix programming problem considering the fuzzy goal. However, since the problem includes random variables and fuzzy numbers, it is not a well-defined problem. Hence, in Section 3, we introduce the probability fractile optimization model and develop its solution method to find a global optimal solution. Furthermore, Section 4 deals with probability maximization model to total future profits and in Section 5, we consider the preference ranking model to each fuzzy goal. In order to illustrate our proposed models, in Section 6 a numerical example is given, and in Section 7 we conclude this paper.

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