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Integrating fuzzy TOPSIS and multi-period goal programming for purchasing multiple products from multiple suppliers

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ABSTRACT

In this paper, a two-phase approach for supplier selection and order allocation problem under a fuzzy environment is proposed. We investigate a problem in which a single buyer orders multiple products from multiple suppliers in multiple periods. To account for inherent ambiguity and vagueness in most real-world data and information, in the first phase of the approach, a fuzzy multiple criteria decision making (FMCDM) method is used to obtain the overall ratings of alternative suppliers, and to select the most qualified ones for further evaluations. In the second phase, using the goal programming (GP) technique, we construct a multi-objective mixed integer linear programming (MOMILP) model to determine the order quantities of each selected supplier for each product in each period. In the MOMILP model, two goals are considered: 1) total value of purchasing (TVP) and 2) meeting the total available periodic budget. Constructing the approach in this way effectively reduces the risk of purchasing. This is because besides evaluating suppliers with regard to a set of quantitative and qualitative criteria, there is also a systematic way to purchase from more than one supplier. Finally, a numerical example is conducted to clarify the proposed approach and to show its usefulness.

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1. Introduction

The supplier selection problem deals with defining potential suppliers, selecting the best set of suppliers among them, and determining the shipment quantity of each (Weber et al., 1991). According to Patton (1997), and Michaels et al. (1995), supplier evaluation and selection is a key element in the industrial buying process, and appears to be one of the major activities of the professional industries. Many industrial managers and practitioners select suppliers based on their experience and perceptions. These approaches are obviously subjective and their weaknesses have been investigated in several studies (e.g., Hwang and Yoon, 1981; Kontio, 1996). In fact, supplier selection has been shown to be a multiple criteria decision making process, and if other real-world considerations are taken into account, may turn out to be an even more complicated problem (Kumar et al., 2006).

As a pioneer in the supplier selection problem, Dickson (1966) identified 23 different criteria for selecting suppliers. These criteria include quality, delivery, performance history, warranties, price, technical capability, and financial position. After Dickson many researchers proposed various MCDM methods for supplier selection. For example, Yahya and Kingsman (1999) used the analytic hierarchy process (AHP) (Saaty, 1980) to determine priorities in selecting suppliers. On the other hand, some other researchers have focused on applying mathematical programming (MP) methods for supplier selection. For example, Weber and Current (1993) analyzed the supplier selection problem as a multiple objective decision.

In traditional practices, first suppliers are selected, and then the buyer, by taking some other considerations and side constraints into account, makes the final decision on how much to order from each. But in the recent decade, researchers have concentrated on integrated approaches in which the issues of supplier selection and order allocation are simultaneously investigated. For example, Ghodsypour and O'Brien (1998) integrated the AHP and linear programming, and proposed a two-stage approach for this problem. Since then, much research in the field of integrated supplier selection and order allocation has been done. However, a large body of these works considers data as crisp and exact. This treatment of data is far from the real-world situations where uncertainty and vagueness is the prominent characteristic.

In this paper, we handle these uncertainty of data and impreciseness of human's judgments through fuzzy sets theory (Zadeh, 1965), and propose a two-phase approach to deal with the multi-product, multi-period, supplier selection and order allocation problem. More specifically, in the first phase, an MCDM approach under fuzzy environment, based on a modified

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Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to obtain the overall ratings of alternative suppliers. As a result of the first phase's evaluations, the most qualified suppliers are selected for further evaluations. In the next phase, using the goal programming (GP) method we construct a multi-objective mixed integer linear programming (MOMILP) model to determine the quantity of each product in each period that should be allocated to each selected supplier. Here, we consider a single buyer who wants to purchase multiple products from multiple suppliers in multiple periods, and whose demand for each product in each period is known in advance. Furthermore, the buyer has set some other considerations, such as the total available budget, and total acceptable defective parts purchased, in making the final decision.

The rest of the paper is organized as follows. In the next section we present a literature review on applications of MCDM and multi-objective decision making (MODM) techniques used for solving the supplier selection and order allocation problem. In Section 3, we propose our two-phase approach for the problem under consideration. In Section 4, a numerical example is presented to show the applicability and usefulness of our proposed approach. Managerial implications and limitations of the proposed approach are discussed in Section 5. Finally, conclusions are given in the last section.

2. Literature review

Supplier evaluation and selection, which includes the process of acquiring required materials, services and equipments for all types of business enterprises, is an important problem in purchasing the necessary materials to support the outputs of any organization (Liu and Hai, 2005). The problem is to evaluate and select the best or most appropriate suppliers for the organization based on various suppliers' capabilities. Basically, there are two types of supplier selection problems—single sourcing and multiple sourcing. In the first type, one supplier can satisfy all the buyer's needs. In this case, the management needs to make only one decision, which supplier is the best. In the second type of supplier selection problems, no supplier can satisfy all the buyer's requirements. In such circumstances management wants to split order quantities among different suppliers for a variety of reasons—including decreasing risk of purchasing and creating a competitive business environment (Demirtas and Ustün, 2008).

Many researchers have dealt with this problem from the mathematical perspective, and construct some kind of optimization model for this purpose. Moore and Fearon (1972) described the possible use of the linear programming (LP) without presenting the exact mathematical formulation. Bender et al. (1985) proposed a mixed integer programming (MIP) model to select suppliers and their order quantities with the objective of minimizing purchasing, inventory, and transportation costs for the IBM company. Sharma et al. (1989) suggested a goal programming formulation in which, price, quality, and lead-time constituted goals, and meeting the demand and the total available budget were the system's constraints. Buffa and Jackson (1983) also proposed the use of the goal programming approach in which price, quality, and delivery comprise goals. Hong and Hayya (1992) proposed a nonlinear mathematical program for this problem. Ghodsypour and O'Brien (2001) developed a mixed integer nonlinear programming model to solve a multiple sourcing problem where they tried to minimize total cost of logistics subject to limitations on budget, quality, service level, etc. Gao and Tang (2003) proposed a multi-objective linear programming model for decisions related to purchasing of raw materials in a large-scale steel plant in China. Weber et al. (2000) implemented the data envelopment analysis (DEA) for selecting suppliers and determining their quota allocations. Ghodsypour and O'Brien (1998) and Wang et al. (2004) proposed two-stage approaches for supplier selection. They used the AHP method to make a trade-off between concrete and vague factors in the decision process, and calculated ratings of suppliers. In the second stage of their approaches, using mathematical programming methods, they effectively selected the suppliers, and allocated orders to each. Demirtas and Ustün, (2008) combined analytic network process (ANP) and a MOMILP model to solve order allocation problem by using a Reservation Level Driven Tchebycheff procedure. They minimized total defect rate, total cost of purchasing, and maximized the TVP. But, however, none of these integrated approaches considered a multi-period planning horizon. Demirtas and Ustün (2009) proposed an integration of ANP and MOMILP for choosing the best supplier, and to determine their shipment allocations, given a number of 14 tangible and intangible criteria that were included in four control hierarchies—Benefits, Opportunities, Costs, and Risks. But they did not consider a multi-product model. Micheli (2008) developed a risk efficiency-based supplier selection approach for critical supplies where he considered the supplier selection issue as a way to mitigate the overall supply risk. For a comprehensive survey on supplier selection problem and its variations, interested reader may refer to Aissaoui et al. (2007).

Most aforementioned studies on supplier selection consider only crisp and exact data in the decision process. This simplification is very far from the real-world situations. In the real world, the rating values of alternatives as well as importance weights of criteria have various types of vagueness or subjectiveness, and one cannot always use the classical decision-making techniques for these decision problems. Therefore, the fuzzy set theory provides a valuable tool for taking these realities into account. In a fuzzy multiple criteria decision making (FMCDM) model, linguistic variables are used to express the subjectiveness and/or imprecision qualitative of a decision-maker's assessments (Chen and Hwang, 1992; Zadeh, 1975).

In recent literature on fuzzy supplier selection problems, Chen et al. (2006) used the fuzzy TOPSIS for supplier evaluation and selection, but they considered only one supplier to purchase from. Kumar et al. (2006) used a fuzzy programming approach for supplier selection, but they did not incorporate intangible criteria in their approach.

To the best of our knowledge, this is the first time that a multi-product, multi-period, supplier selection and order allocation problem under a fuzzy environment is addressed through a two-phase approach. In the following section we present our approach in detail.

3. The proposed approach

In this section we describe our two-phase approach for supplier selection and order allocation problem. Note that, before the first phase can be initiated, it is sometimes necessary for the buyer to do an initial screening on the list of its potential suppliers. This screening stage is intended to restrict the pool of potential suppliers to those which, for example, supply the required parts/materials, or those with a good performance history (e.g., grade "A" suppliers). Then, the suppliers, in the restricted pool, are evaluated and scored through a fuzzy MCDM method. Once all suppliers' scores are calculated, those which have a score higher than a threshold value, called the minimum acceptable score, are selected for being incorporated in the second phase of the proposed approach. In the second phase, a

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