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A weighted max–min model for fuzzy multi-objective supplier selection in a supply chain

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ABSTRACT

Supplier selection is one of the most important activities of purchasing departments. This importance is increased even more by new strategies in a supply chain. Supplier selection is a multi-criteria decision making problem in which criteria have different relative importance. In practice, for supplier selection problems, many input information are not known precisely. The fuzzy set theories can be employed due to the presence of vagueness and imprecision of information. A weighted max–min fuzzy model is developed to handle effectively the vagueness of input data and different weights of criteria in this problem. Due to this model, the achievement level of objective functions matches the relative importance of the objective functions. In this paper, an analytic hierarchy process (AHP) is used to determine the weights of criteria. The proposed model can help the decision maker (DM) to find out the appropriate order to each supplier, and allows the purchasing manager(s) to manage supply chain performance on cost, quality and service. The model is explained by an illustrative example.

1. Introduction

Within new strategies for purchasing and manufacturing, suppliers play a key role in achieving corporate competitiveness. Hence, selecting the right suppliers is a vital component of these strategies. In most industries the cost of raw materials and component parts constitutes the major cost of a product, such that in some cases it can account for up to 70% (Ghobadian et al., 1993). Thus the purchasing department can play a key role in an organization's efficiency and effectiveness because of the contribution of supplier performance on cost, quality, delivery and service in achieving the objectives of a supply chain. Supplier selection is a multiple criteria problem that includes both qualitative and quantitative factors. The relative importance of the criteria and sub-criteria are determined by top management and purchasing managers based upon supply chain strategies.

In a real case, decision makers do not have exact and complete information related to decision criteria and constraints. In these cases the theory of fuzzy sets is one of the best tools to handle uncertainty. Fuzzy set theories are employed in the supplier selection problem due to the presence of vagueness and imprecision of information. Amid et al. (2006) developed a weighted additive fuzzy model for supplier selection problems to deal with: imprecise inputs and the basic problem of determining the weights of quantitative/qualitative criteria under conditions of multiple sourcing and capacity constraints. In a weighted additive model, there is no guarantee that the achievement levels of fuzzy goals are consistent with desirable relative weights or the DM's expectations. When the DM provides the weight of the objective functions, the ratio of membership functions achievement level should be as close as possible to the ratio of objective weights in order to reflect the relative importance of the criteria. However in the weighted additive model, the ratio of achievement levels is not necessarily the same as that of the objective weights.

In this paper, a weighted max–min fuzzy multi-objective model has been developed to enable the purchasing managers to assign the order quantities to each supplier based on supply chain strategies.

2. Literature review

Dickson (1966) first identified and analyzed the importance of 23 criteria for supplier selection based on a survey of purchasing managers. Weber et al. (1991) reviewed 74 articles discussing supplier selection criteria. They also concluded that supplier selection is a multi-criteria problem and the priority of criteria depends on each purchasing situation. Roa and Kiser (1980) and

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Bache et al. (1987) identified, respectively, 60 and 51 criteria for supplier selection.

Weber and Current (1993) used a multi-objective approach to systematically analyze the trade-offs between conflicting criteria in supplier selection problems. Ghodsypour and O'Brien (1997, 1998) developed an integrated AHP and linear programming model to consider both qualitative and quantitative factors in a purchasing activity. Karpak et al. (1999) used a goal programming model to minimize costs and maximize delivery reliability and quality in supplier selection when assigning the order quantities to each supplier. Degraeve and Roodhooft (2000) developed a total cost approach with mathematical programming to treat supplier selection using activity based cost information. Ghodsypour and O'Brien (2001) developed a mixed-integer non-linear programming approach to minimize total cost of logistics, including net price, storage, ordering costs and transportation in supplier selection. Cebi and Bayraktar (2003) proposed an integrated model for supplier selection. They used an integrated lexicographic goal programming (LGP) and AHP to consider both quantitative and qualitative conflicting factors. Barla (2003) proposed the supplier selection and evaluation for a manufacturing company under lean philosophy. The supplier selection and evaluation process was conducted by multi-attribute selection model (MSM) in five basic steps. Demirtas and Ustün (2008) proposed an integrated approach using analytic network process (ANP) with multi-objective mixed integer linear programming (MOMILP) to consider both tangible and intangible factors in choosing the best suppliers and define the optimum quantities among selected suppliers to maximize the total value of purchasing and minimize the budget and defect rate. Ng (2008) proposed a weighted linear model and a transformation technique to solve a multi-criteria supplier selection problem. Some authors have used fuzzy set theory (FST) to deal with uncertainty. In fuzzy programming, the decision-maker (DM) is no longer forced to formulate the problem in a precise and rigid form. Based on fuzzy logic approaches, Erol and Ferrel (2003) proposed a methodology that assists decision-makers to use qualitative and quantitative data in a multi-objective mathematical programming model. The methodology uses fuzzy QFD to convert qualitative information into quantitative parameters. They used this methodology for selecting the best software system for a particular application. Kwang et al. (2002) introduced a combined scoring method with fuzzy expert systems approach for determination of best supplier. Kahraman et al. (2003) developed a fuzzy AHP model to select the best supplier firm providing the most satisfaction for the criteria determined. Dogan and Sahin (2003) proposed a supplier selection model for multi-periods under uncertainty conditions. The supplier selection process is performed by choosing the supplier that minimizes the present total additional costs associated with the purchase decision. The activity-based cost is used in their model.

These papers deal with single sourcing supplier selection in which one supplier can satisfy all buyers' needs. However, our model discusses multiple sourcing (Ghodsypour and O'Brien, 1998). Kumar et al. (2004) proposed fuzzy goal programming for the supplier selection problem with multiple sourcing that includes three primary goals: minimizing the net cost, minimizing the net rejections and minimizing the net late deliveries, subject to realistic constraints regarding buyer's demand and vendors' capacity. In their proposed model, a weightless technique is used in which there is no difference between objective functions. In other words, the objectives are assumed equally important in this approach and there is no possibility for the DM to emphasize objectives with heavy weights. In the real situation for supplier selection problems, the weights of criteria are different and depend on purchasing strategies in a supply chain (Wang et al., 2004).

As stated above, Amid et al. (2006, 2009) developed a weighted additive fuzzy model for supplier selection problems to deal with: imprecise inputs and the basic problem of determining weights of quantitative/qualitative criteria under conditions of multiple sourcing and capacity constraints. In their weighted additive model, there is no guarantee that the achievement levels of fuzzy goals are consistent with desirable relative weights or the DM's expectations (Chen and Tasi, 2001; Amid et al., 2006).

In this paper, a weighted max–min fuzzy multi-objective model has been developed for the supplier selection problem to overcome the above problem. This fuzzy model enables the purchasing managers not only to consider the imprecision of information but also to take the limitations of buyer and supplier into account in calculating the order quantities from each supplier. The analytic hierarchy process (AHP) approach is often suggested for solving a complex problem and it has been applied in a wide variety of decision making contexts (Saaty, 1978, 1990). It also provides a structured approach for determining the weights of criteria. AHP is used to determine the weights of criteria in the model presented.

The paper is organized as follows: Section 3 presents the fuzzy multi-objective model and its crisp formulation for the supplier selection problem in which the objectives are not equally important and have different weights. First, a general linear multi-objective formulation for this problem is considered and then some definitions and appropriate approach for solving this decision making problem are discussed. Section 4 gives the numerical example and explains the results. Finally, the concluding remarks are presented in Section 5.

3. The multi-objective supplier selection model

A general multi-objective model for the supplier selection problem can be stated as follows (Weber and Current, 1993):

$$\text{Min } Z_1, Z_2, \ldots, Z_k \tag{1}$$

$$\text{Max } Z_{k+1}, Z_{k+2}, \ldots, Z_p \tag{2}$$

subject to:

$$x \in X_d, \quad X_d = \{x / g_s(x) \le b_s, \quad s = 1,2,\ldots,m\} \tag{3}$$

in which the $Z_1, Z_2, \ldots, Z_k$ are the negative objectives or criteria for minimization like cost, late delivery, etc. and $Z_{k+1}, Z_{k+2}, \ldots, Z_p$ are the positive objectives or criteria for maximization such as quality, on time delivery, after sale service and so on. X_d is the set of feasible solutions that satisfy the set of system and policy constraints.

It is clear that the supplier selection problem is an optimization problem, which requires that formulation of objective functions. Not every criterion in this problem is quantitative. This problem is recognized by Ghodsypour and O'Brien (1998). They proposed an integrated method that uses AHP to deal with both qualitative and quantitative criteria. A comprehensive review of criteria for supplier selection is presented in Ghodsypour and O'Brien (1996). He concluded that the number and the weights of criteria depend on purchasing strategies.

To have a typical model, the purchasing criteria are assumed to be quality, net price and delivery in this paper. These objectives were cited most often in ordering decision (Roa and Kiser, 1980; Ghodsypour and O'Brien, 1998).

In order to formulate this model, the following notations are defined:

D	demand over period
x_i	the number of units purchased from the ith supplier