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An novel approach to supplier selection based on vague sets group decision

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ABSTRACT

In practice, in purchasing decision-making, many quantitative and qualitative factors, with vagueness and imprecision, have to be considered. This makes the decision process very complicated and unstructured. Besides the fuzzy sets theory, vague sets theory is one of the methods used to deal with uncertain information. Since vague sets can provide more information than fuzzy sets, it is considered superior in mathematical analysis of uncertain information. In this paper, a new approach based on vague sets group decision is proposed to deal with the supplier selection problem in supply chain systems. The work procedure is shown briefly, as follows: First, linguistic values are used to assess the ratings and weights for quantitative or qualitative factors. Second, degree of similarity and probability of vague sets are used to determine the ranking order of all alternatives. Finally, a numerical example of the selection problem of suppliers is shown, to highlight the procedure of the proposed approach, at the end of this paper.

1. Introduction

With the globalization of economic markets and the development of information technology, a well-designed and implemented supply chain management (SCM) system is now regarded as an important tool to increase competitive advantage (Choi, Bai, Geunes, & Romeijn, 2007; Li, Yamaguchi, & Nagai, 2007). In upstream echelons of supply chain, vendor selection or supplier evaluation continues to be a key element in the industrial purchasing process, and appears to be one of the major activities of the professionals in the industry (Patton, 1997; Michaels, Kumar, & Samu, 1995). Supplier selection and evaluation is the process of finding the appropriate suppliers who are able to provide the buyer with the right quality products and/or services at the right price, in the right quantities and at the right time (Mandal & Deshmukh, 1994; Sarkis & Talluri, 2002).

Evaluation and selection of suppliers is a typical multiple criteria decision-making (MCDM) problem involving multiple criteria that can be both qualitative and quantitative. The MCDM provides an effective framework for vendor comparison, based on evaluation of multiple and often conflicting criteria. There is an abundance of supplier evaluation and selection models proposed in supply chain literature. The main methods are linear weighting methods (LW) (Thompson, 1990; Timmerman, 1986), analytic hierarchy process (AHP) (Barbarosoglu & Yazgac, 1997; Narasimhan, 1983), analytic network process (Sarkis & Talluri, 2000), total cost approaches (Monezka & Trecha, 1998; Smytka & Clemens, 1993) and mathematical programming (MP) techniques (Buffa & Jackson, 1983; Chaudhry, Forst, & Zydiak, 1993).

Although linear weighting is a very simple method, it depends heavily on human judgment and also weighs the attributes equally, which is rarely true, in practice. While MP techniques cause significant problems in considering qualitative factors, AHP cannot effectively take into account risk and uncertainty in estimating the suppliers' performance because it presumes that the relative importance of attributes affecting the suppliers' performance is known with certainty (Dyer, Fishburn, & Steuer, 1992). The drawback of MP is that it requires arbitrary aspiration levels and cannot accommodate subjective attributes (Khorramshahgol, Azani, & Gousty, 1988).

Most of these methods do not seem to address the complex and unstructured nature and context of many present day purchasing decisions (de Boer, van der Wegen, & Telgen, 1998). In fact, in many existing decision models, only quantitative criteria are considered for supplier selection. Several important factors are often not taken into account in the decision-making process, such as incomplete information, additional qualitative criteria and imprecise preferences. Based on the vast literature on supplier selection (Choi & Hartley, 1996; Weber, Current, & Benton, 1991), we can conclude that supplier selection may involve several and different types of criteria, combinations of different decision models, group decision-making and various forms of uncertainty. It is difficult to find the best way to evaluate and select supplier, companies use a

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variety of different methods to deal with it. Therefore, the most important issue in the process of supplier selection is to develop a suitable method to select the right supplier.

In essence, the supplier selection problem in supply chain is a group decision-making problem, under multiple criteria. The degree of uncertainty, the number of decision-makers (DMs) and the nature of the criteria have to be taken into account while solving this problem. The decision-makers always express their preferences on alternatives or on attributes of suppliers, which can be used to rank the suppliers or in selecting the most desirable ones. The preferences on different suppliers and on attributes are DMs' subjective judgments. In conventional MCDM methods, ratings and weights of the attributes are known precisely (Delgado, Verdegay, & Vila, 1992; Hwang & Yong, 1981; Kaufmann & Gupta, 1991). Generally, DMs' judgments are uncertain and cannot be estimated by exact numerical values. Under many conditions, crisp data are inadequate to model real-life situations; human judgments, including preferences, are often vague and preferences cannot be estimated in exact numerical values.

In recent years, fuzzy set approaches have been proposed to deal with the supplier selection problem under uncertainty (Wang, 2005). A more realistic approach may be to use linguistic assessments, instead of numerical values. In other words, ratings and weights of the criteria in the problem are assessed by means of linguistic variables (Bellman & Zadeh, 1970; Chen, 2000; Herrera, Herrera-Viedma, & Verdegay, 1996; Herrera & Herrera-Viedma, 2000). The fuzzy set theory offers a possibility of handing data and information involving subjective characteristics of human nature in the decision-making process. Kickert (1978) has discussed fuzzy multi-criteria decision-making. Zimmermann (1987) illustrated a fuzzy set approach to multi-objective decision-making; he has compared some approaches to solve multi-attribute decision-making problems based on the fuzzy set theory. Yager (1978) presented a fuzzy multi-attribute decision-making method that uses crisp weights, and in 1988, he introduced an ordered weighted aggregation operator and investigated its properties (Yager, 1988). Laarhoven and Pedrycz (1983) presented a method for multi-attribute decision-making, using fuzzy numbers as weights. But these methods have a shortcoming that the fuzzy set is not fuzzy completely; for example, their fuzzy values are also exact. To improve the fuzzy set, Gau and Buehrer (1993) proposed the vague set theory. Then, based on the vague set theory, Chen and Tan (1994) presented some new techniques for handling multi-criteria fuzzy decision-making problems. Hong and Choi (2000), Jun (2007) extended the study on vague sets-based MCDM method.

In this paper, we have proposed a new approach based on vague sets group decisions to deal with the problem of supplier selection under uncertain environments. In supplier selection process, the degree of uncertainty of the attributes has to be taken into account (Chen, Lin, & Huang, 2006). Considering the fuzziness in the decision data, in the group decision-making process, linguistic variables that can be expressed in vague values are used, to assess the weights of all criteria and the ratings of each alternative with respect to each criterion. Linguistic variables are also used to determine weights of the importance of different decision-makers; then we adjust the weights by considering the similarities and differences among them. After that, we integrate the judgments of all decision-makers into a final decision matrix. Using probability degree to compare the vague sets of the evaluation object, we obtain the ranking order of every alternative.

The paper is organized as follows. The next section introduces the basic definitions and notations of the vague sets. In Section 3, we present a fuzzy decision-making method based on vague sets to cope with the supplier selection problem. And then, the proposed method is illustrated with an example. Finally, some conclusions are drawn at the end of this paper.

2. The basic theory

2.1. Vague sets

Let U be the universe of discourse, with a generic element of U denoted by u. A vague set $A$is characterized by a truth-membership function t_A and a false-membership function f_A, where $t_A(u)$ is a lower bound on the grade of membership of u, derived from the evidence for u; $f_A(u)$ is a lower bound on the negation of u, derived from the evidence against u; and $t_A(u) + f_A(u) \leqslant 1$. The grade of membership of u in the vague set A is bound to a subinterval $[t_A(u), 1 - f_A(u)]$ of $[0,1]$. The vague value $[t_A(u), 1 - f_A(u)]$ indicates that the exact grade of membership $\mu_A(u)$ of u maybe unknown, but it is bound by $t_A(u) \leqslant \mu_A(u) \leqslant 1 - f_A(u)$, where $t_A(u) + f_A(u) \leqslant 1$. For example, Fig. 1 shows a vague set in the universe of discourse$U$.

When the universe of discourse U is continuous, a vague set A can be written as

$$A = \int_U [t_A(u), 1 - f_A(u)]/u \quad (u \in U).$$

When the universe of discourse U is discrete, a vague set A can be written as

$$A = \sum_{i=1}^{n} [t_A(u_i), 1 - f_A(u_i)]/u_i \quad (u_i \in U).$$

2.2. Operation between vague sets

Let x, y be two vague values in the universe of discourse U, $x = [t_x, 1 - f_x]$, $y = [t_y, 1 - f_y]$, where $t_x, f_x, t_y, f_y \in [0,1]$ and $t_x + f_x \leqslant 1, t_y + f_y \leqslant 1$; the operation and relationship between vague values is defined as follows:

Definition 1. The minimum operation of vague values x and y is defined by

$$x \wedge y = [\min(t_x, t_y), \min(1 - f_x, 1 - f_y)] = [\min(t_x, t_y), 1 - \max(f_x, f_y)].$$

Definition 2. The maximum operation of vague values x and y is defined by

$$x \vee y = [\max(t_x, t_y), \max(1 - f_x, 1 - f_y)] = [\max(t_x, t_y), 1 - \min(f_x, f_y)].$$

Definition 3. The complement of vague value x is defined by

$$\bar{x} = [f_x, 1 - t_x].$$

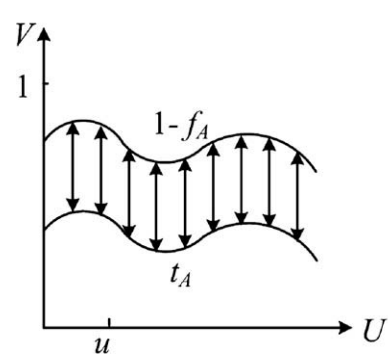

Fig. 1. Vague set.