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A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting

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ABSTRACT

Recently, resolving the problem of evaluation and ranking the potential suppliers has become as a key strategic factor for business firms. With the development of intelligent and automated information systems in the information era, the need for more efficient decision making methods is growing. The VIKOR method was developed to solve multiple criteria decision making (MCDM) problems with conflicting and non-commensurable criteria assuming that compromising is acceptable to resolve conflicts. On the other side objective weights based on Shannon entropy concept could be used to regulate subjective weights assigned by decision makers or even taking into account the end-users' opinions. In this paper, we treat supplier selection as a group multiple criteria decision making (GMCDM) problem and obtain decision makers' opinions in the form of linguistic terms. Then, these linguistic terms are converted to trapezoidal fuzzy numbers. We extended the VIKOR method with a mechanism to extract and deploy objective weights based on Shannon entropy concept. The final result is obtained through next steps based on factors *R*, *S* and *Q*. A numerical example is proposed to illustrate an application of the proposed method.
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1. Introduction

Nowadays, the problem of supplier selection has emerged as an active research field where numerous research papers have been published around this area within last few years. Supplier selection plays a key role in supply chain management (SCM) and deals with evaluation, ranking and selection of the best option from a pool of potential suppliers especially in the presence of conflicting criteria. Jiang, Zhuang, and Lin (2006) evinces the considerable impact of supplier selection and integration on customer satisfaction and business performance.

With the development of information systems, it is becoming an important issue for SCM frameworks and applications to be capable of making decisions on their own (Shemshadi, Soroor, & Tarokh, 2008; Soroor, Tarokh, & Shemshadi, 2009), and it is not attainable until a well devised decision making process is deployed by an adequately improved software architecture.

In the literature, supplier selection has been treated as a multiple criteria decision making (MCDM) and a wide range of mathematical methods have been undertaken to provide the problems with sufficient and more accurate solutions (Boer, Labro, & Morlacchi, 2001; Ho, Xu, & Dey, 2010). Among these methods we can mention artificial intelligence and knowledge discovery techniques such as genetic algorithm (Che & Wang, 2008; Liao & Rittscher, 2007; Hwang & Rau, 2008), artificial neural networks (Chen, Xuan, & Shang, 2009; Lee & Ou-Yang, 2009; Wei, Zhang, & Li, 1997; Wu, Liu, & Xi, 2008), and data mining (Kai, Xin, & Dao-ping, 2009); mathematical programming methods such as data envelopment analysis (Wu, 2009), linear programming (Amid, Ghodsypour, & O'Brien, 2006; Guneri, Yucel, & Ayyildiz, 2009), AHP and nonlinear programming (Kokangul & Susuz, 2009), rough set theory (Chang, Hung, & Lo, 2007), and grey system theory (Huixia & Tao, 2008); MCDM and GMCDM methods such as AHP (Chamodrakas, Batis, & Martakos, 2010; Lee, 2009; Xia & Wu, 2007), ANP (Gencer & Gürpinar, 2007; Luo, Wu, Rosenberg, & Barnes, in press; Razmi, Rafiei, & Hashemi, in press), TOPSIS (Boran, Genc, Kurt, & Akay, 2009; Rhee, Verma, & Plaschka, 2009); and other methods and techniques (Chou & Chang, 2008; Keskin, İlhan, & Özkan, in press; Zhang, Zhang, Lai, & Lu, 2009).

In MCDM problems, since that the valuation of criteria leads to diverse opinions and meanings, each attribute should be imported with a specific importance weight (Chen, Tzeng, & Ding, 2003). A question rises up here and that is "how this importance weight could be calculated"? In literature, most of the typical MCDM methods leave this part to decision makers, while sometimes it would be useful to engage end-users into the decision making process. To obtain a better weighting system, we may categorize

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weighting methods into two categories: subjective methods and objective methods (Wang & Lee, 2009). While subjective methods determine weights solely based on the preference or judgments of decision makers, objective methods utilize mathematical models, such as entropy method or multiple objective programming, automatically without considering the decision makers' preferences. The approach with objective weighting is particularly applicable for situations where reliable subjective weights cannot be obtained (Deng, Yeh, & Willis, 2000).

On the other side, new researches entail new MCDM approaches such as VIKOR. Recently, due to its characteristics and capabilities, the VIKOR method has been considerably undertaken by researchers to provide decision making problems, especially in the field of supplier selection, with more accurate solutions. This includes deploying VIKOR either solely (Chiang, 2009; Chen & Wang, 2009) or along with other mathematical or MCDM approaches such as AHP (Liu & Yan,, 2007; Wu, Chen, & Chen, 2010), ANP (Liou & Chuang, in press), rough sets (Jiagang & Wei, 2008; Zhou & Tian, 2008), and artificial neural networks (Chen & Li, 2008).

In this article, we provide an introduction to the *VIKOR* method, *Fuzzy Logic* and the *Shannon Entropy* respectively at sections 2–4. We are going to propose the new method in Section 5 while Section 6 provides it with a numerical example. Section 7 concludes the paper.

2. VIKOR method

Vlsekriterijumska Optimizacija I Kompromisno Resenje (i.e. VIKOR) method was developed by Opricovic in 1998 for multi-criteria optimization of complex systems (Opricovic, 1998; Opricovic & Tzeng, 2002). VIKOR focuses on ranking and sorting a set of alternatives against various, or possibly conflicting and non-commensurable, decision criteria assuming that compromising is acceptable to resolve conflicts. Similar to some other MCDM methods like TOPSIS, VIKOR relies on an aggregating function that represents closeness to the ideal, but the unlike TOPSIS, introduces the ranking index based on the particular measure of closeness to the ideal solution and this method uses linear normalization to eliminate units of criterion functions (Opricovic & Tzeng, 2004).

In VIKOR the multi-criteria measure for compromise ranking is developed from the $L_p - metric$ used as an aggregating function in a compromise programming method (Yu, 1973; Zeleny, 1982). The measure $L_{p,j}$ that was introduced by by Duckstein and Opricovic (1980) represents the distance of the alternative A_j from the best ideal solution. Each one of the various J alternatives, represented as A_1, $A2, \ldots, A_J$, is measured against the ith criteria, shown by C_i, is denoted by f_{ij}.

The VIKOR method was developed with the form of $L_p - metric$, shown as follows:

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[w_i (f_i^* - f_{ij}) / (f_i^* - f_i^-) \right]^p \right\}^{1/p} \quad (1)$$
$$1 \leqslant p \leqslant \infty; \quad j = 1, 2, \ldots, J$$

The VIKOR method deploys $L_{1,j}$ (as S_j) and $L_{\infty,j}$ (as R_j) to formulate the ranking measure. The solution obtained by $\min_j\{S_j\}$ is with a maximum group utility and the solution obtained by $\min_j\{R_j\}$ is with a minimum individual regret of the opponent. The compromise solution F^C is a feasible solution that is the closest to the ideal F^*, and compromise means an agreement established by mutual concessions, as illustrated in Fig. 1.

$\Delta F_1 = f_1^* - f_1^C$ and $\Delta F_2 = f_2^* - f_2^C$.

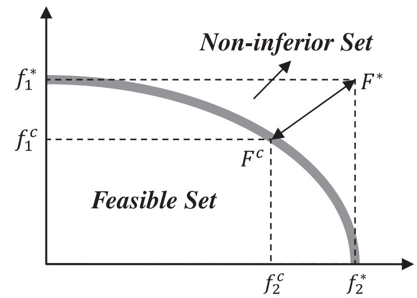

Fig. 1. Ideal and compromise solutions.

3. Fuzzy logic

Fuzzy set theory first was introduced by Zadeh (1965) to map linguistic variables to numerical variables within decision making processes. Then the definition of fuzzy sets were manipulated to develop Fuzzy Multi-Criteria Decision Making (FMCDM) methodology by Bellman and Zadeh (1970) to resolve the lack of precision in assigning importance weights of criteria and the ratings of alternatives against evaluation criteria. The traditional logic tools generally are considered outcome of bivalent (binary) logics, while problems that pose in the real world are by no means bivalent (Tong & Bonissone, 1980).

Just as conventional, bivalent logic is based on classic sets, fuzzy logic is based on fuzzy sets. A fuzzy set is a set of objects in which there is no clear-cut or predefined boundary between the objects that are or are not members of the set. A fuzzy set is characterized by a membership function, which assigns to each element a grade of membership within the interval [0,1], indicating to what degree that element is a member of the set (Bevilacqua, Ciarapica, & Giacchetta, 2006). As a result, in fuzzy logic general linguistic terms such as "bad", "good" or "fair" could be used to capture specifically defined numerical intervals.

A fuzzy number is defined as a fuzzy set such that

$$M = \{(x), \mu_M(x), x \in R\} \quad (2)$$

where $\mu_x(x)$ is a continuous mapping from R to the closed interval [0,1].

3.1. Trapezoidal fuzzy numbers (TFN)

A TFN can be denoted as a tuple $\{(n_1, n_2, n_3, n_4) | n_1, n_2, n_3, n_4 \in R; n_1 \leqslant n_2 \leqslant n_3 \leqslant n_4\}$ which respectively, denote the smallest possible, the most promising, and the largest possible values that describe a fuzzy term. Here, we can define the membership function as follows:

$$\mu_N(x) = \begin{cases} (x - n_1)/(n_2 - n_1), & x \in [n_1, n_2] \\ 1 & x \in [n_2, n_3] \\ (n_4 - x)/(n_4 - n_3), & x \in [n_3, n_4] \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

A TFN is shown in Fig. 2.

4. Shannon entropy and objective weights

As we mentioned before two different weights are used in the proposed method: objective weights and subjective weights. Subjective weights could be obtained directly from the decision makers' opinions like many other MCDM processes.

Shannon and Weaver (1947) proposed the entropy concept, which is a measure of uncertainty in information formulated in terms of probability theory. Since the entropy concept is well

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