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A new compromise solution method for fuzzy group decision-making problems with an application to the contractor selection

Behnam Vahdani [a,*], S. Meysam Mousavi [b], H. Hashemi [b], M. Mousakhani [c], R. Tavakkoli-Moghaddam [d]

[a] Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran
[b] Young Researches Club, South Tehran Branch, Islamic Azad University, Tehran, Iran
[c] Department of Business Management, Faculty of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran
[d] Department of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

This paper presents a novel compromise solution method for solving fuzzy group decision-making problems by a group of experts, which can determine the best alternative by considering both conflicting quantitative and qualitative evaluation criteria in real-life applications. The compromise solution method is developed based on the concept that the chosen alternative should be as close as possible to the positive ideal solution and as far away from the negative ideal solution as possible concurrently. The performance rating values of alternatives versus conflicting criteria as well as the weights of criteria are described by linguistic variables with multi-judges and are converted to triangular fuzzy numbers. Then, a new collective index is introduced to distinguish among potential alternatives in the assessment process with respect to subjective judgment and objective information. Finally, a real case study and an application example for a contractor selection problem are provided in construction industry to demonstrate the implementation process of the proposed method.

1. Introduction

Multiple criteria decision-making (MCDM) method is a useful technique for determining the best solution among potential alternatives versus multiple criteria with different effects. In practice, it is usually impossible for a solution to completely satisfy all conflicting criteria. Hence, Pareto optimality is introduced to be applied to MCDM methods. In fact, if one alternative obtains a good score with respect to one criterion, it is least likely that in other criteria the same good score is achieve. Alternatives possess their own strengths with respect to different criteria which may not be consistent. Therefore, a Pareto optimal solution may be utilized (Chang, 2010). Extensions of the compromise solution methods, e.g., VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian) and TOPSIS (technique for order preference by similarity to an ideal solution), are based on the concept of Pareto optimality.

The increasing complexity of the decision support systems causes practitioners to take advantage of a group of experts or decision makers (DMs) to analyze all relevant aspects of decision-making problems. In the recent decade, some researchers have focused on MCDM problems to obtain reliable results by considering the assessment of the DMs instead of the assessment of an individual DM (e.g., Chen and Hwang, 1992; Deng et al., 2000; Mojtahedi et al., 2010; Kuo et al., 2007; Vahdani and Hadipour, 2011). On the other hand, MCDM methods contain the DMs' subjective judgments and preferences, including qualitative and/or quantitative criteria ratings as well as the weights of criteria (Vahdani et al., 2013; Mousavi et al., 2012a, 2012b). This issue has further intensified the uncertainty of assessments inherent in decision-making process. Under this situation, experts or DMs may not be able to apply precise numbers to describe their assessments; however, they can utilize linguistic variables by their knowledge and experience. With this approach, they can provide more realistic and reasonable judgments and feelings. Hence, the concept of fuzzy numbers can be integrated into the group decision making under multiple criteria known as fuzzy multiple criteria group decision-making (MCGDM), and can be regarded as an effective approach to solve complex decision-making problems (Shih et al., 2007; Vahdani et al., 2011).

In the last decade, several attempts have been made to propose compromise solution methods for the MCGDM problems under a fuzzy environment. For instance, Chen (2000) developed the TOPSIS method for the group decision making in a fuzzy environment. The performance rating of alternatives and the criteria weights are presented by linguistic terms and then described in triangular fuzzy numbers. Chen et al. (2006)

* Corresponding author. Tel.: 98 2182084183
E-mail addresses: b.vahdani@gmail.com (B. Vahdani), sm.mousavi@ut.ac.ir (S.M. Mousavi).

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presented a fuzzy approach based on the concept of the TOPSIS method for supplier evaluation and selection in supply chain management. Linguistic variables are utilized to analyze the ratings and weights for the main criteria and then are represented in trapezoidal or triangular fuzzy numbers. Ebrahimnejad et al. (2010) proposed an approach based on fuzzy TOPSIS method in order to rank higher risks in mega projects. The final ranking is conducted based on fuzzy Euclidean distance and triangular fuzzy number. Vahdani et al. (2011) developed a group decision-making approach based on a fuzzy modified TOPSIS method for the manufacturing decisions with two examples for the robot selection and rapid prototyping process selection.

Opricovic and Tzeng (2007) considered a VIKOR method with a stability analysis determining the weight stability intervals. Then, the VIKOR was compared with three MCDM methods, namely TOPSIS, PROMETHEE, and ELECTRE. Yang et al. (2009) proposed a VIKOR-based method to improve the gaps in control items to achieve the aspired level for information security risk. Vahdani et al. (2010) presented a compromise solution method based on traditional VIKOR method and the interval-valued fuzzy set concept, aiming at solving MCDM problems in which the weights of criteria are unequal. Chang (2010) investigated existing problems in the traditional VIKOR method and extended a modified VIKOR method to avoid numerical difficulties in solving decision-making problems by this method. Liou et al. (2011) applied a modified VIKOR method for improving domestic airlines service quality. A large sample was utilized to obtain a complete service quality evaluation framework for reducing the gaps to achieve the aspired level. Jahan et al. (2011) extended a modified VIKOR method for material selection particularly in biomedical application where the implant materials could possess similar properties to those of human tissues. Opricovic (2011) proposed a fuzzy VIKOR with an application to water resources planning, which was based on the aggregating fuzzy merit that represented distance of an alternative to the ideal solution. Mousavi et al. (2011) presented a fuzzy stochastic multi-attribute group decision-making approach for selection problems in which a group of the DMs described a value for an alternative versus an attribute by the use of linguistic variables. The rating of each alternative was aggregated, which could be expressed as triangular fuzzy numbers. Then, a stochastic VIKOR method was proposed to evaluate probability distributions for each alternative on each attribute.

The review of the literature indicates that the fuzzy compromise solution method has received much less attention for solving the group decision-making problems; there is a need for simple and logical mathematical tool to help the DMs in order to make a best decision. Thus, in this paper a new compromise solution method is proposed based on the VIKOR method by a group of DMs in a fuzzy environment. In this method, the performance rating values of each alternative under the conflicting criteria as well as the weights of criteria are linguistic variables represented by triangular fuzzy numbers. Then, a new collective index is introduced to rank alternatives under a fuzzy environment.

The proposed compromise solution method is different from the previous studies in a number of significant aspects as given below: (1) Two new indices are developed based on the strategy of the majority criteria and the individual regret in order to consider the relative distance of alternatives from the positive and negative ideal solutions simultaneously, unlike the previous studies which did not consider the relative distance; (2) a novel collective index is introduced to distinguish among alternatives in the assessment process by concurrently constructing ideal separation and anti-ideal separation matrixes; (3) the combined effect of the weight of the majority of criteria and the weight of the individual regret, which can be highly important in the ranking process of the compromise solution methods, is clearly regarded using new assessment indices rather than the previous studies; (4) the proposed compromise solution method constructs the ideal separation and anti-ideal separation matrixes based on the operations between triangular fuzzy numbers to discriminate among the alternatives in the group decision-making problems, unlike the previous studies which were based on Euclidean distances of each alternative with respect to the reference points; and (5) the proposed method considers both subjective judgment and objective information (both crisp and fuzzy numbers) for the group decision-making problem in real-life applications.

This method is established upon the concept of positive ideal and negative ideal solutions concurrently for solving group decision-making problems with multi-criteria and multi-judges under uncertainty. Finally, a real case study and an application example for the purpose of the contractor selection illustrate utilizing the presented fuzzy compromise solution method in construction industry.

The remaining of this paper is structured as follows: In Section 2, the traditional VIKOR method is briefly introduced. New fuzzy compromise solution method is proposed to solve MCGDM problems in Section 3. Section 4 presents the case study and an application example for the contractor selection problem in the construction industry. The paper is concluded in Section 5.

2. VIKOR method

A compromise solution for a decision-making problem with conflicting criteria can help the DMs to make a reliable decision. Establishing a compromise solution is usually preferred rather than an optimal solution because of conflicting tangible and intangible criteria. The foundation for a compromise solution was first introduced by Yu (1973) and Zeleny (1982) and later followed by Opricovic (1998), and Opricovic and Tzeng (2002, 2004). The compromise solution is a feasible solution which is the closest to the ideal solution representing an agreement reached by mutual concessions. Two analytical multi-criteria techniques, namely TOPSIS and VIKOR, are often regarded as the well-known compromise solution methods for the MCDM problems. These methods are widely applied to numerous management and engineering fields (e.g., Mousavi et al., 2011; Vahdani et al., 2010).

Over the recent decades, other MCDM methods have been presented such as PROMETHEE and ELECTRE. These MCDM methods differ in many theoretical background and type of results given (Ebrahimnejad et al., 2012). Some MCDM methods have been constructed especially for one specific problem, and they are not suitable for other decision problems. For detail discussions, readers are referred to Ebrahimnejad et al. (2010, 2012).

Suppose an MCDM problem that has m alternatives, $A_1,\ldots,A_m$ and n criteria, $C_1,\ldots,C_n$. Each alternative is assessed with respect to the n criteria. The rating of alternative i with respect to criterion j is denoted by f_{ij}, and the best and worst values are regarded as f_j^* and f_j^-, respectively. All the performance ratings assigned to the alternatives versus each criterion from a decision matrix are denoted by $X=(x_{ij})_{m\times n}$. Let $W=(w_1,w_2,\ldots,w_n)$ be the relative weight vector about the criteria, satisfying $\sum_{j=1}^{n} w_j=1$. Then, the VIKOR method can be summarized as follows (Opricovic and Tzeng, 2002, 2004):

Step 1. Determine the best f_j^* and the worst f_j^- values of all criteria functions $j=1,2,\ldots,n$. If the jth function represents a benefit then:

$$f_j^* = \max_i f_{ij} \tag{1}$$