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An extended VIKOR method using stochastic data and subjective judgments

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ABSTRACT

Decision makers (DMs) face different levels of uncertainty throughout the decision making process. In particular, natural language is generally subjective or ambiguous when used to express perceptions and judgments. The aim of this paper is to extend the VIKOR method and develop a methodology for solving multi-criteria decision making (MCDM) problems with stochastic data. The weights of the stochastic decision criteria considered in our extended VIKOR model have been determined using the fuzzy analytic hierarchy process (AHP) method. We present a case study in the banking industry to demonstrate the applicability of the proposed method. We also compare our results with the results obtained from a stochastic version of the super-efficiency data envelopment analysis (DEA) model to exhibit the efficacy of the procedures and algorithms.

1. Introduction

Multi-criteria decision making (MCDM) refers to making preference decisions (e.g., evaluation, prioritization and selection) over a set of available alternatives that are characterized by multiple and often conflicting criteria. Moreover, since decision making generally requires multiple perspectives from different people, most organizational decisions are made in groups (Ma, Lu, & Zhang, 2010). MCDM is used to select the most desirable alternative(s) from a set of available alternatives based on the selection criteria defined (Ju & Wang, 2013).

The classical MCDM frameworks assume that the ratings and the weights of the criteria are known precisely. However, many real-world problems involve uncertain data and one cannot assume the knowledge and judgments of the decision makers (DMs) or experts to be precise (Sayadi, Heydari, & Shahanaghi, 2009). MCDM models account for different types of uncertainties, which are generally modeled using stochastic analysis or fuzzy set theory. The stochastic approach is more suitable when a probabilistic data set represents the existing uncertainty, while the fuzzy approach is more appropriate when the parameters are vague and ambiguous (Zarghami & Szidarovszky, 2009).

The VIKOR method was introduced by Opricovic in 1998 to model the multi-criteria optimization of complex systems (Opricovic, 1998). This method focuses on ranking and selecting from a set of available alternatives in the presence of conflicting criteria by proposing a compromise solution (composed by either one or several alternatives) (Opricovic & Tzeng, 2007). A compromise solution is often preferred to an optimal solution because selection criteria are usually in conflict. The best alternative is chosen to be the one with the smallest distance to the positive ideal solution using a particular measure of "closeness".

The VIKOR method is suitable for those situations where the goal is to maximize profit while the risk of the decisions is deemed to be less important. The major advantage of the VIKOR method is that it can trade off the maximum group utility of the "majority" and the minimum individual regret of the "opponent". In addition, the required calculations are simple and straightforward (Bazzazi, Osanloo, & Karimi, 2011).

In this paper, we extend the basic structure of VIKOR and develop a methodology for solving MCDM problems where the data describing the performance of the alternatives are stochastic. The proposed model considers multiple stochastic criteria, whose

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weights have been determined applying the fuzzy analytic hierarchy process (AHP) method to the linguistic judgments provided by different experts. We present a case study in the banking industry to demonstrate the applicability of the proposed method. Moreover, we compare our results with the results obtained from a stochastic version of the super-efficiency data envelopment analysis (DEA) model in order to exhibit the efficacy of the procedures and algorithms.

The remainder of this paper is organized as follows. The next section provides a short review of the VIKOR literature. A brief introduction to the VIKOR method is presented in Section 3. In Section 4, the extended stochastic VIKOR method proposed is described. Section 5 provides an illustrative example to show the applicability of the extended VIKOR method. Section 6 compares the ranking obtained using our model with the one derived from applying the super-efficiency stochastic DEA model. Section 7 concludes and suggests future research directions.

2. Literature review and contribution

The VIKOR method has been extensively applied to solve different types of MCDM problems both in certain settings and in fuzzy environments with subjective judgments.

Within the former settings, Chang and Hsu (2009) used VIKOR to prioritize land-use restraint strategies in the Tseng–Wen reservoir watershed. Sayadi et al. (2009) extended the VIKOR method in order to solve decision making problems with interval numbers. Liou, Tsai, Lin, and Tzeng (2010) used a modified VIKOR method for improving the service quality of domestic airlines. Chatterjee, Athawale, and Chakraborty (2009) applied the VIKOR procedure to the selection process of materials for flywheel and sailing boat mast design. These authors obtained a complete ranking of the materials by considering many criteria related to the actual applications of the respective products. In this regard, Civic and Vucijak (2014) considered several selected criteria to evaluate insulation options that increase energy efficiency in buildings and applied the VIKOR method to rank the options and select the best one.

The use of fuzzy sets gives DMs enough flexibility to incorporate unquantifiable, incomplete and partial information into a decision model (Chou, Hsu, & Chen, 2008). Fuzzy MCDM, with the capacity to resolve the lack of precision in measuring the importance weights of the criteria and the corresponding ratings of alternatives, has been widely applied to address decision making problems with multiple criteria and alternatives in a consistent way. For instance, Chang (2014) proposed a framework based on several concepts from fuzzy set theory and the VIKOR method to provide a systematic process for evaluating the quality of hospital services in a fuzzy environment.

Indeed, many researchers have incorporated elements from different fuzzy environments into their modified VIKOR models. For example, Chen and Wang (2009) optimized the choice of partners in IS/IT outsourcing projects following a fuzzy VIKOR approach. Sanayei, Mousavi, and Yazdankhah (2010) and Shemshadi, Shirazi, Toreihi, and Tarokh (2011) developed different fuzzy VIKOR methods for a supplier selection problem with linguistic ratings and weights. In addition, the latter authors used an entropy measure to assign the weights of the criteria. Recent applications of the fuzzy VIKOR method are quite varied and range from water resource planning (Opricovic, 2011) to the selection of robots for handling materials (Devi, 2011).

Finally, as we do in the current paper, the fuzzy VIKOR method has been integrated with other MCDM techniques to determine the ranking of alternatives. Kuo and Liang (2011) evaluated the service quality of airports using a MCDM technique that combined fuzzy VIKOR and grey relational analysis. Kaya and Kahraman (2010) designed an integrated fuzzy VIKOR and AHP methodology for multi-criteria renewable energy planning in Istanbul. In the same way, Kaya and Kahraman (2011) integrated VIKOR and the AHP method to select alternative forestation areas. They determined the weights of the criteria using a fuzzy AHP approach in order to allow for both pairwise comparisons and the utilization of linguistic variables.

In this regard, our model considers a fuzzy scenario where linguistic expert evaluations are used to determine the weights of the decision criteria. Thus, similarly to the latter authors, the weights that follow from these evaluations have been computed using a fuzzy AHP approach. Then, these weights have been integrated within VIKOR to provide a ranking of the different alternatives. However, differently from the above models, ours assumes that the data available to measure the performance of the alternatives are stochastic. As a result, our model allows the DMs to integrate within VIKOR linguistic evaluations regarding the relative importance of the criteria used to classify alternatives whose performance is described by stochastic data.

3. The VIKOR method

The basic idea of the VIKOR technique, a MCDM method introduced by Opricovic (1998), consists of defining positive and negative ideal points to determine the relative distance of each alternative. After each relative distance is calculated, a weighted compromise ranking is obtained to determine the importance of the m alternatives available, x_j, with $j = 1, 2, \ldots, m$. VIKOR provides a particularly effective tool in MCDM situations where the DM is unable "to express his/her preference at the beginning of system design" (Opricovic & Tzeng, 2004, p. 448). The compromise-ranking algorithm is composed of the following steps:

1. Define the rating functions f_{ij}, which provide the value of the i-th criterion function for alternative x_j, with $i = 1, 2, \ldots, n$. Calculate the best, f_i^+, and the worst, f_i^-, values of all criterion functions. If the criterion being consider constitutes a benefit (i.e. it is a positive criterion), the corresponding values are defined as follows

$$f_i^+ = \max[(f_{ij})|j = 1, 2, \ldots, m] \tag{1}$$

$$f_i^- = \min[(f_{ij})|j = 1, 2, \ldots, m] \tag{2}$$

2. Compute the values S_j and R_j, $j = 1, 2, \ldots, m$, using the following relations

$$S_j = \sum_{i=1}^{n} w_i \frac{(f_i^+ - f_{ij})}{(f_i^+ - f_i^-)} \tag{3}$$

$$R_j = \max_i \left[w_i \frac{(f_i^+ - f_{ij})}{(f_i^+ - f_i^-)} \right] \tag{4}$$

where S_j and R_j represent the group utility measure and the individual regret measure defined for each alternative x_j, respectively, and w_i are the weights of the criteria that reflect their relative importance.

3. Compute the values Q_j, $j = 1, 2, \ldots, m$, using the relation

$$Q_j = v\left[\frac{(S_j - S^+)}{(S^- - S^+)}\right] + (1 - v)\left[\frac{(R_j - R^+)}{(R^- - R^+)}\right] \tag{5}$$

where

$$S^+ = Min[(S_j)|j = 1, 2, \ldots, m] \tag{6}$$

$$S^- = Max[(S_j)|j = 1, 2, \ldots, m] \tag{7}$$