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A simulation based multi-attribute group decision making technique with decision constraints

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ABSTRACT

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a useful technique for solving Multi Attribute Group Decision Making (MAGDM) problems. In MAGDM, the performance scores of the alternatives and the weights of assessment attributes are mostly vague. Therefore, using of deterministic data throughout decision making process may lead to inaccurate results. In order to overcome inherent vagueness and uncertainty, various fuzzy MAGDM techniques were presented in the literature. However, these fuzzy MAGDM techniques are focused on expected and extreme values, which are sometimes insufficient for the precise determination of alternatives' preference structure. In this paper, in order to eliminate the limitations of deterministic and fuzzy MAGDM methods, we present a probabilistic methodology, which is based on TOPSIS and Monte-Carlo simulation of triangular data. In addition to its straightforward application and thanks to its versatility, simulation enables decision makers to incorporate some decision constraints into decision-making process. Two illustrative examples are also given to show the effectiveness of the proposed methodology. The method is also compared with a fuzzy TOPSIS technique from the literature.

1. Introduction

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A decision maker (*DM*) or a group of *DM*s often encounter the problem of selecting a solution from a given set of finite number of alternatives. A multi-attribute decision making (MADM) problem can be briefly described as the selection of the best alternative among *m* alternatives while trading-off between *n* attributes considering the relative importance of the attributes [1]. MADM refers to evaluating, prioritizing and selecting a set of alternatives, which are characterized by multiple and generally conflicting attributes [2].

The TOPSIS is a useful and powerful method for dealing with MADM problems. TOPSIS is based on the suggestion that the most suitable alternative or the compromise solution should be farthest from the negative ideal solution (*NIS* – the least desirable) and the closest to the positive ideal solution (*PIS* – the most desirable). The *PIS* and the *NIS* are imaginary alternatives defined by the best and the worst attainable performance levels of the attributes, respectively. As addressed by [3,4], its main strengths are (i) the consideration of the best and the worst alternatives simultaneously, (ii) the straightforward computation process, and (iii) the ease of visualization of all or some of the alternatives on a polyhedron. For this reason, the technique is suitable for *DM*s to rank alternatives and to select the most appropriate among them.

In Fig. 1 [5], the positions of the *PIS* and the *NIS* are illustrated in a two dimensional space. Each dimension represents an attribute. As shown in Fig. 1, the *PIS* is the combination of the best attainable attribute performances while conversely, the *NIS* is the combination of the worst attainable attribute performances. These are actually imaginary and shouldn't coincide with any of the alternatives. Otherwise, there would be no reason for such a decision making effort. For this reason, the alternative which is the farthest from the *NIS* and the closest to the *PIS* is searched.

The TOPSIS has been used in many fields thanks to its simple physical meaning and ease of implementation. Its capability of direct handling of performance measures, makes the TOPSIS a stronger technique compared to the techniques that employ pairwise comparisons. Especially for scenarios with dozens or more alternatives, the TOPSIS is a good alternative. Therefore, it has still been widely used as a decision making tool in many fields. For a comprehensive review on the TOPSIS, readers are referred to [6].

In many organizations, decisions are made collaboratively. Group decision making (GDM) is the process of obtaining a solution or solutions for a problem with respect to the information supplied

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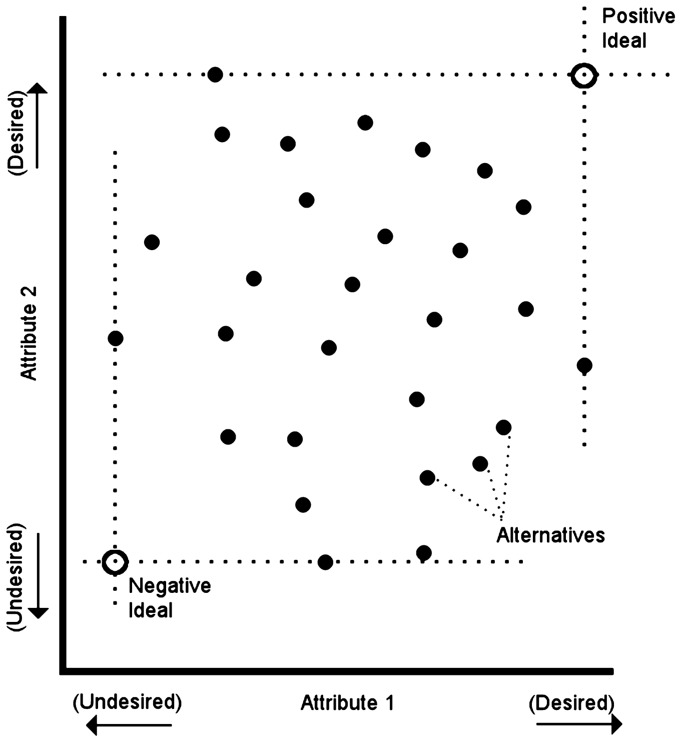

Fig. 1. Positions of PIS, NIS and alternatives in alternative space.

by multiple *DMs*. Its aim is to derive the best satisfactory solution across the group [7]. The combination of MADM and GDM techniques, namely MAGDM, was suggested in order to effectively rank and select the solution alternatives while considering the level of overall satisfaction across the group of *DMs* [8].

In MAGDM environment, the information about the attribute weights and the performance ratings of alternatives are mostly imprecise. Some reasons for this impreciseness are: (1) information loss due to the quantification of qualitative attributes, (2) non-obtainable information, (3) conflicting preferences and priorities of *DMs* [9,10]. In order to deal with inherent impreciseness and subjectiveness, the fuzzy set theory [11] has been integrated with many MAGDM techniques [12–15]. Ölçer and Odabaşı [16] used a fuzzy MAGDM for propulsion and maneuvering system selection. Huang et al. [17] implemented fuzzy analytic hierarchy process (AHP) for the R&D project selection. Awasthi et al. [18] implemented fuzzy TOPSIS for supplier performance evaluation. Samvedi et al. [19] used both fuzzy TOPSIS and Fuzzy AHP techniques to quantify risks in a supply chain. Then, they consolidate the values into a comprehensive risk index. Li and Wan [20] proposed fuzzy inhomogenous MAGDM approach based on TOPSIS and they solved a MAGDM problem of outsourcing provider selection. Lima Junior et al. [21] compared fuzzy TOPSIS and fuzzy AHP methods for supplier selection. Taylan et al. [22] implemented both fuzzy AHP and fuzzy TOPSIS methods for construction project selection and risk assessment. Meng and Chen [23] presented a method that deals with incomplete fuzzy preferences of *DMs*. Zavadskas et al. [24] developed a fuzzy AHP based methodology for the selection of deep sea port. Efe et al. [26] implemented fuzzy AHP for ERP system selection.

Another approach to deal with impreciseness is stochastic approach. In the stochastic approach, some or all of the input parameters are defined by using probability distributions. Lahdelma and Salminen [27] suggested a method which considers both the weight and the attribute values to be inaccurate. Their method explores the weight space in order to describe the valuations that would make each alternative the preferred one. Refs. [28,29] proposed a stochastic MADM technique based on PROMETHEE for the land use decision making problem. Prato [30] used a stochastic multiple attribute evaluation for the selection of land use policy where the different stakeholders had different attribute preferences. Performance attributes of the alternatives were described by using triangular distribution. Mousavi et al. [7] proposed a fuzzy-stochastic MADM approach by aggregating group preferences into fuzzy numbers. After performing Monte Carlo simulation of triangular fuzzy numbers, probability distributions that represent the performance of alternatives with respect to attributes are found. Then, a compromise ranking technique for final prioritization of alternatives is used. Lafleur [5] used triangular distribution to model the weight impreciseness of the attributes in pairwise comparison matrix of AHP. Then, the preference probabilities of alternatives were analyzed by employing Monte Carlo simulation. Liu et al. [31] proposed an extended TOPSIS method. Their approach is based on probability theory and uncertain linguistic variables. In their study, attribute weights were assumed to be unknown. The attribute values were uncertain linguistic variables under the interval probability.

Despite its straightforwardness, the basic formulation of TOPSIS has been criticized due to its incapability of handling uncertainty and impreciseness stemming from the process of mapping the *DM* preferences. In the standard TOPSIS method, the performance judgments of alternatives are represented by crisp values, which are unsuitable for real world applications [32]. In fact, these values are usually uncertain. Therefore, the TOPSIS has been extended to fuzzy TOPSIS in order to deal with both MADM and MAGDM problems [12,13,33]. Fuzzy TOPSIS has been implemented several times in literature [25,34–40]. Fuzzy techniques in the literature are focused on the extreme and the expected performances of alternatives. Namely, they use the best case, the worst case and the most probable case for the determination of best alternative, but intermediate occurrences are overlooked. Analyzing the extreme realizations is not a necessary solution as these realizations are rare events with low probability of occurrence [28,29]. Moreover, some fuzzy techniques defuzzify fuzzy numbers and that causes information loss and deteriorates the ability of fuzzy techniques to handle uncertainty [41]. Moreover, the determination of the performance ratings by exact (crisp) or stochastic information under GDM is either very difficult, time demanding or impossible [7]. Hence, there is still a need for a more complete understanding of the possible outcomes of decision making process where both weight and performance scores are expressed in fuzzy numbers [10,42]. For this reason, simulation can be a good alternative to use in decision making process.

In this paper, a method that establishes a stochastic viewpoint for MAGDM problems, was proposed. The method considers imprecision and subjectiveness that stems from the *DMs* judgments. It employs Monte Carlo simulation in order to simulate the variation between decisions made by different *DMs* and to see how the final decisions are affected from this variation. If the decisions of different *DMs* are the same, then simply using a single value or other central value could be meaningful. On the other hand, when the decisions of *DMs* are not the same, a central value may not be sufficient. The difference between the most pessimistic value, the most possible value and the most optimistic value constitutes a measure of dispersion that represents the level of consensus or disparity in the decisions of the *DMs*. Simulation of preferences of the group provided a complete understanding of alternatives' preference structure. Similar to the studies of [30] and [7], aggregation of *DM* preferences are used as the stochastic input of the simulation. Then, simulation provides the preference probabilities of alternatives. In order to demonstrate the effectiveness of the proposed technique, two numerical examples are solved. In one

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