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An extended compromise ratio model with an application to reservoir flood control operation under an interval-valued intuitionistic fuzzy environment

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ABSTRACT

This paper presents a novel multiple attribute group decision-making (MAGDM) model based on the compromise ratio method under an interval-valued intuitionistic fuzzy (IVIF) environment. The compromise ratio method under uncertainty is introduced by a group of experts based on the concept that the chosen alternative should be as close as possible to the IVIF-positive-ideal point and as far away from the IVIF-negative-ideal point as possible concurrently. First, an IVIF-weighted geometric averaging (IVIFWGA) operator is employed to aggregate all individual IVIF-decision matrices provided by a group of experts into a collective IVIF-decision matrix. Two new basic IVIF-operations are introduced to handle the evaluation process. Then, an extended collective index in an IVIF environment is proposed to discriminate among alternatives for the evaluation process in terms of subjective and objective information. Finally, to demonstrate the suitability and applicability of the proposed IVIF-MAGDM model, an application example of reservoir flood control operation is given from the recent literature.

1. Introduction

Since the primary work of Zadeh [1], the traditional 0–1 logic was developed to fuzzy logic, described by a membership function between 0 and 1. This development leads to important theoretical extensions and widely used approaches that are successfully applied in many engineering and management fields (e.g., [2–7]). In the last two decades, intuitionistic fuzzy sets (IFSs) were first presented by Atanassov [8] as an extension of Zadeh's fuzzy sets. The IFSs are implemented in numerous industrial applications with remarkable results (e.g., [9–11]). By considering the real-valued membership and non-membership functions represented in interval values, Atanassov and Gargov [12] introduced the notion of the IFSs to interval-valued intuitionistic fuzzy sets (IVIFSs). The basic feature of the IVIFS is that the values of its membership function and non-membership function are intervals rather than exact numbers [13]. Thus, the IVIFSs can properly take into consideration the ambiguity in the information as well as the fuzziness in experts or decision makers (DMs)' preferences and judgments in order to involve different aspects of problems in real-life decision making.

Many real-life decision problems can be taken within the frame of multiple attribute group decision making (MAGDM). The purpose of the MAGDM is to choose an appropriate alternative among a set of alternatives by assessing multiple conflicting attributes by a group of experts. Such decision problems can be solved by using several existing reputable

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MAGDM methods, namely GVIKOR (group Vlse Kriterijuska Optimizacija I Komoromisno Resenje) and GTOPSIS (group technique for order preference by similarity to ideal solution), developed by Opricovic [14] and Hwang and Yoon [15], respectively. Both GVIKOR and GTOPSIS methods are taken into account an aggregation function by characterizing the closeness to the ideal point. These methods can easily structure the problem corresponding to the DMs' needs along with adopted results [16–19].

For the relate literature, some researchers have taken the VIKOR and TOPSIS methods under incomplete and uncertain environment. For instance, Opricovic and Tzeng [20] developed the VIKOR method for analyzing the planning strategies by reducing the future social and economic costs in the area with potential natural hazard. Tzeng et al. [21] applied and compared VIKOR and TOPSIS methods to determine the best compromise alternative fuel model in solving a public transportation problem. Chang and Hsu [22] applied the VIKOR method to determine the best feasible solution according to the selected criteria, including geographical and meteorological factors. The objective of their study was to establish the priority ranking of land-use restrictions in the Tseng-Wen reservoir watershed. Hashemi et al. [23] applied the VIKOR method based on intuitionistic fuzzy sets under multiple criteria to select the potential alternatives in a large-scale water resources development scheme. Vahdani et al. [24] presented the interval-valued fuzzy VIKOR method and built a practical maintenance strategy selection problem to verify their proposed method. Mousavi et al. [3] proposed a stochastic VIKOR method for selection problems in which a group of the DMs described a value for an alternative vs. an attribute by the use of linguistic variables. Opricovic [25] utilized the fuzzy VIKOR method to study the development of a reservoir system for the storage of surface flows of the Mlava River and its tributaries for regional water supply. Liou et al. [26] applied a modified VIKOR method to improve service quality among domestic airlines in Taiwan. Their model allows DMs to understand the gaps between alternatives and aspired-levels in practice. Vinodh et al. [27] selected the VIKOR method for concept selection in the agile manufacturing. Mishra et al. [28] adopted VIKOR method in a fuzzy environment to assess multiple attributes on suppliers' performance and to select the best supplier among a group of alternative suppliers. Girubha and Vinodh [29] used the VIKOR as a decision making tool for the selection of alternate material for instrument panel used in electric car and in order to evaluate this selection process in fuzzy environment. Park et al. [30] extended TOPSIS method to handling MAGDM problems under an IVIF-environment where the information about attributes' weights is partially known. Park et al. [31] developed a procedure for solving MAGDM problems and extended the VIKOR method, in which all the preference information provided by the DMs is presented as IVIF-decision. Yücenur and Demirel [32] extended fuzzy VIKOR method to deal with the criteria and select the most suitable alternative insurance. The VIKOR method focused on ranking from a set of alternatives in the presence of conflicting criteria under fuzzy environment. Vahdani et al. [33] presented a new compromise solution method by a group of experts or the DMs with traditional fuzzy sets to effectively solve the evaluation and selection problems. The method is applied to the contractor selection problem with multi-criteria and multi-judges under uncertainty.

The review of the literature shows that the compromise ratio method under modern fuzzy environment can be introduced as a new research area for solving complex decision problems through the group decision making process. Although the existing approaches have had contributions to decision making under uncertainty, most of the related literature (e.g., [3,5,32,33]) described the individual decision information with traditional fuzzy sets.

This paper presents a novel MAGDM model based on an extended compromise ratio method in an IVIF environment. The major contributions of this paper are given below:

- Two new operations for interval-valued intuitionistic fuzzy sets are presented by taken the operational laws of interval-valued intuitionistic fuzzy numbers (IVIFNs) into consideration.
- In the proposed compromise ratio method, IVIF-ideal separation and anti-ideal separation matrixes are constructed based on the new subtraction operations between IVIFNs to discriminate among the alternatives in the group decision-making problems, unlike the previous studies which were based on traditional fuzzy sets and distances of potential alternatives from the ideal solutions.
- An extended collective index in an IVIF-environment is proposed to rank alternatives according the concept of the relative distance from the IVIF-positive-ideal and IVIF-negative-ideal points and the score and accuracy functions, unlike the previous studies (e.g., [30,31]) which were based on Euclidean distances of each alternative with respect to the reference points and Ref. [33] with traditional fuzzy numbers.
- The model has the ability to reflect both subjective judgment and objective information in real-life applications under an IVIF environment. Characteristics of alternatives and decision attributes are represented by linguistic terms and then are converted into IVIFNs.

It is worth to mention that the compromise ratio method presented by the authors [33] is employed in this paper for the evaluation process; however, the main contributions and differences of the proposed model combined with a modern fuzzy set in an IVIF-form are explained above unlike the previous studies (e.g., [30,31]). Furthermore, application example from the recent literature is examined for the reservoir flood control operation to demonstrate the implementation process of the IVIF-MAGDM model. The model can assist the DMs to make their efficient decisions for solving intricate decision problems under uncertainty.

A limitation of the proposed IVIF-MAGDM as a generalized decision making model under uncertainty is that it employs a new subtraction operation for calculating the distance between two IVIFNs. This operation is valid under some conditions. In fact, these conditions should be met through the decision process. In some states, the experts or DMs may be