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Interval-valued intuitionistic fuzzy QUALIFLEX method with a likelihood-based comparison approach for multiple criteria decision analysis

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ABSTRACT

QUALIFLEX (i.e., QUALItative FLEXible multiple criteria method) is a useful outranking method used for multiple criteria decision analysis. This paper uses the main structure of QUALIFLEX to develop an interval-valued intuitionistic fuzzy QUALIFLEX outranking method with a likelihood-based comparison approach for handling multiple criteria decision-making problems within a decision environment of interval-valued intuitionistic fuzzy sets. We propose the concept of using the likelihood of fuzzy preference relations to compare interval-valued intuitionistic fuzzy numbers. To address diversiform preference types, we represent the decision-maker's various forms of preference structures and assess the criterion weights using incomplete information. Using a criterion-wise preference of alternatives via comparison of the likelihoods, we develop a new QUALIFLEX-based model to measure the level of concordance of the complete preference order for managing multiple criteria decisions. The feasibility and applicability of the proposed methods are illustrated using a practical example, namely, the selection of a suitable bridge construction method. A comparative analysis with other relevant methods is conducted to validate the effectiveness of the proposed methodology.

1. Introduction

Atanassov and Gargov [3] introduced the concept of interval-valued intuitionistic fuzzy sets (IVIFSs), which are generalizations of intuitionistic fuzzy sets (IFSs) [1,2]. The IVIFSs are characterized by a membership function and a non-membership function that take on values that are intervals rather than exact numbers. In human cognitive and decision-making activities, it is not completely justifiable or technically sound to quantify grades of membership and non-membership in terms of a single numeric value [38]. Thus, IVIFSs with interval-valued membership and non-membership functions have received increasing attention because of their ability to handle imprecise and ambiguous information in real-world applications. The IVIFSs have been used in a wide range of applications, especially in multiple criteria decision analysis (MCDA). A considerable number of studies have reported decision-making models and methods within the IVIFS environment, such as score functions [17,56], accuracy functions [17,32], weighted correlation coefficients [57], hybrid weighted distance measures [60], decision functions with risk attitude [16], rule-based group decision models [4], rational decision-making models with incomplete weight information [39], optimization models [15,48], auxiliary nonlinear programming models [27,45],

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preference relations and aggregation operators [13], induced correlated averaging and geometric operators [49], hybrid Shapley averaging operators [30,31], dice similarity measures based on reduct IFSs [55], extended TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [25,37,42], extended LINMAP (LINear programming technique for Multidimensional Analysis of Preference) [6], a generalized method for student answer-scripts evaluations [10], and a gray relational analysis method [7,50]. Many studies have developed MCDA methods in the context of IVIFSs, but most of these methods consist of scoring or compromise models. The interval-valued intuitionistic fuzzy outranking models are less developed, particularly the QUALIFLEX methodology.

The QUALIFLEX method, introduced by Paelinck [33–35], is a variation of Jacquet–Lagreze's permutation method [24]. QUALIFLEX is a useful outranking method in MCDA because of its flexibility with respect to cardinal and ordinal information [19,21]. The QUALIFLEX method was developed to address ranking problems [40] and approaches MCDA problems by testing how each possible ranking of alternatives is supported by different criteria [22,26]. Several useful extensions have been developed to enhance the QUALIFLEX method. For example, Griffith and Paelinck [19] extended QUALIFLEX to develop a qualitative regression method known as QUALIREG. Chen et al. [14] developed an intuitionistic fuzzy permutation method to measure the level of concordance of the complete preference order, which can be applied to cardinal or ordinal evaluations of alternatives. Considering that optimism and pessimism are measured via optimistic and pessimistic point operators, respectively, Chen and Tsui [11] proposed a QUALIFLEX method for relating optimism and pessimism within an intuitionistic fuzzy decision environment. Furthermore, the QUALIFLEX methodology has been extended to a type-2 fuzzy environment. Interval type-2 fuzzy sets, which are also known as interval-valued fuzzy sets, are the most widely used type of type-2 fuzzy sets because of their relative simplicity [8,29]. Chen and Wang [12] extended Jacquet–Lagreze's permutation method by developing an interval-valued fuzzy permutation method for solving MCDA problems. Based on the type-2 fuzzy framework, Chen et al. [9] developed an extended QUALIFLEX method for handling MCDA problems in the context of interval type-2 trapezoidal fuzzy numbers.

Although the usefulness and applicability of the QUALIFLEX method in decision-making fields have been thoroughly investigated, notably few attempts have been made to extend QUALIFLEX to the interval-valued intuitionistic fuzzy decision environment. Therefore, in this paper, a new QUALIFLEX method based on IVIFSs has been developed to capture more imprecise or uncertain decision information and to address MCDA problems. We conducted this study to construct a new outranking model, i.e., the QUALIFLEX methodology, which involves likelihood-based comparisons for solving MCDA problems within the IVIFS environment.

The purpose of this paper is to develop an interval-valued intuitionistic fuzzy QUALIFLEX method with a likelihood-based comparison approach for handling MCDA problems. We present the concept of the lower and upper likelihoods of the fuzzy preference relations between interval-valued intuitionistic fuzzy numbers (IVIFNs), and we further define a likelihood measure of fuzzy preference relations in an interval-valued intuitionistic fuzzy context. We establish a likelihood-based comparison approach to identify the concordance/discordance index. Additionally, we represent the decision-maker's various forms of preference structures using incomplete (i.e., imprecise or partial) information. The optimal weight vector of the criteria and the optimal comprehensive concordance/discordance index for each permutation of the alternatives are directly generated from the solution results using a linear programming model with consistent weight information or by an integrated nonlinear programming model with inconsistent weight information. Next, we select the optimal permutation that exhibits the greatest comprehensive concordance/discordance index and obtain the corresponding ranking order of the alternatives.

This paper makes several significant contributions to the existing literature on outranking decision-making models for MCDA problems based on IVIFSs. First, this paper establishes a likelihood-based comparison approach for measuring the levels of concordance and discordance of the complete priority order of the alternatives. Second, this paper proposes an innovative way to incorporate the likelihoods of fuzzy preference relations into the core structure of QUALIFLEX under incomplete preference information, an approach that is novel and different from previously developed methods. Third, this paper develops a systematic approach that involves the QUALIFLEX-based method to enrich the outranking methodology in interval-valued intuitionistic fuzzy settings.

This article is organized as follows. Section 2 briefly reviews the concepts of IVIFSs and formulates an MCDA problem using IVIFSs. Section 3 presents the likelihood of fuzzy preference relations in the IVIFS context. Section 4 develops a likelihood-based QUALIFLEX method for managing interval-valued intuitionistic fuzzy decision making with incomplete preference information. Furthermore, this section establishes a linear programming model to determine the criterion weights under limited weight information. Section 5 examines the feasibility and applicability of the proposed method by illustrating how this method can be applied in practice to a case in which a bridge construction method is selected. This section also provides a comparative analysis using the intuitionistic fuzzy QUALIFLEX method and the widely used fuzzy TOPSIS method. Finally, Section 6 presents our conclusions and future research.

2. Interval-valued intuitionistic fuzzy representation

Several of the relevant definitions and operations of IVIFSs are briefly reviewed in this section. Additionally, this section establishes a decision environment based on IVIFSs. Because the decision-maker's method of evaluating alternatives and making decisions is guided by his or her subjective judgments, the ratings of alternative evaluations used in MCDA can be expressed as IVIFSs.