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Intuitionistic fuzzy multi-attribute group decision-making with an application to plant location selection based on a new extended VIKOR method

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ABSTRACT

This paper presents a new decision method for multi-attribute group decision-making (MAGDM) problems in general and plant location selection (PLS) problem in particular, with intuitionistic fuzzy information captured through trapezoidal intuitionistic fuzzy numbers (TrIFNs). We assume that the weights of the decision-makers and attributes are completely unknown. The ratings of alternatives with respect to each attribute are considered as linguistic terms, which are mapped to the appropriate TrIFNs. To reduce subjective randomness in the decision-process, we determine attribute weights using the Shannon entropy theory, and weights of the decision-makers by integrating the Evidence theory with Bayes approximation. Furthermore, we extend the classical VIKOR method to solve MAGDM problems under intuitionistic fuzzy environment based on the TrIFNs. Considering that the PLS problem is essentially a MAGDM problem that involves evaluation of the alternatives on several conflicting attributes based on the vague and imprecise assessments of the decision-makers, we demonstrate utility of the proposed decision method by applying it solve the PLS problem. A detailed comparison is presented to demonstrate the advantages of the proposed methodology over the existing methods used for both the intuitionistic fuzzy MAGDM problems and PLS problem.

1. Introduction

In today's highly competitive market, real-world decision-making has indeed become indispensable often possessing multiple conflicting and non-commensurable evaluation standards. Consequently, most of the real-world decision-making problems can be viewed as multiple attribute decision-making (MADM) [16] problems that are used in cases of discrete and limited number of alternatives characterized by multiple and conflicting attributes. The attributes are classified in two ways; firstly, as subjective (qualitative/intangible), objective (quantitative/tangible) and critical (that need to be satisfied before further processing) attributes, and secondly, as benefit type (the more the better) and cost type (the less the better) attributes. The main advantage of MADM is that it can provide many dimensions to the decision-maker for considering the related elements, and evaluate all possible alternatives under variable degrees. Furthermore, to reinforce democracy and rationality

[1] Dedicated to my dearest parents Smt. VIMAL GUPTA and Sh. GOVIND RAM.

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of the decision-making, many real-world processes take place in group settings. Multiple attribute group decision-making (MAGDM) [17] is a key component of group decision-making, and is among the most important and frequently encountered process in a variety of important application fields including engineering, economy, management, medicine, military affairs, etc. Moreover, in practical group decision-making, because of the complexity and subjectivity of the decision systems and the indefinite source of human judgment, the evaluation results given by the decision experts are not necessarily crisp numbers, but may be linguistic terms or labels of fuzzy sets [47] as for the qualitative attributes, quantification of the uncertain information is a difficult task. This has led to the emergence of fuzzy multiple attribute group decision-making (FMAGDM) [7] methods that are needed to treat imprecise, vague and uncertain information, both qualitative and quantitative.

In many practical FMAGDM problems, there may exist hesitation in either evaluation process or in the preferences of the attributes. The intuitionistic fuzzy set (IFS) [1] is more useful and flexible in dealing with fuzziness and uncertainty originating from vague knowledge or information involving hesitation. The IFS theory is considered to solve the imprecision of cognitive thinking of humans due to its prominent characteristic that both the attached and non attached information can be taken into consideration in the decision-process. The IFS theory has been successfully integrated with MADM and MAGDM approaches [2–5]. Genç et al. [14] studied the issue of consistency, missing value(s) and derivation of the priority vector of interval fuzzy preference relations. Boran and Akay [6] proposed a biparametric similarity measure for IFSs with applications to pattern recognition. Shen et al. [26] proposed a new outranking sorting method for group decision making using IFSs. Wan et al. [36] developed a new method for solving MAGDM problems with Atanassov's interval-valued intuitionistic fuzzy values and incomplete attribute weight information.

Along with increasing complexity of the decision environment, multitudes of novel expression forms of the IFSs are constantly advanced in the literature. Wang [38] defined the trapezoidal intuitionistic fuzzy number (TrIFN), which is an extension of the triangular intuitionistic fuzzy number (TIFN). TIFNs and TrIFNs extend the domain of the IFS from the discrete to the continuous setting. Compared with the IFSs, the TrIFNs are defined using trapezoidal fuzzy numbers where the membership degree and non membership degree are no longer relative to a fuzzy concept of excellence, but relative to the trapezoidal fuzzy number. The TrIFNs may express more flexible and abundant information than the trapezoidal fuzzy numbers.

Recently, the researchers have shown increased interest and concern on the applications of MADM and MAGDM with reference to use of the TrIFNs. Wu and Cao [39] developed some geometric aggregation operators for aggregating TrIFNs and applied them to MAGDM problems. Zhang et al. [48] defined a grey relational projection method for MADM problems based on TrIFN. Wan [33] developed a new decision method based on power average operator of TrIFNs and applied it to MAGDM problems. Ye [41] introduced the expected values for TrIFNs and presented a method to handle MADM problems. Wan and Dong [35] developed some power geometric operators of TrIFNs and applied them to MAGDM problems with TrIFNs. Li and Chen [20] proposed a new MAGDM method using consistency analysis for the trapezoidal intuitionistic fuzzy TOPSIS method. Ye [42] established similarity measures based on the Hamming and Euclidean distances between the TrIFNs to solve the MAGDM problem. Li and Chen [21] presented a new extended TOPSIS method with TrIFNs and prospect theory for MAGDM problems. Shen et al. [25] presented a new arithmetic aggregation operator called I-ITFOWA and developed a MAGDM process utilizing the proposed operator and the ITFWAA operator in the intuitionistic trapezoidal fuzzy setting. Dutta and Guha [11] investigated Bonferroni mean aggregation operator under intuitionistic trapezoidal fuzzy environment and proposed a weighted MADM technique. Shi [27] investigated the dynamic MADM problem under intuitionistic trapezoidal fuzzy environment and developed a new operator called dynamic intuitionistic trapezoidal fuzzy weighted geometric averaging operator.

Among the many available methods, the VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian, means Multi Criteria Optimization and Compromise Solution) method [22] is an applicable technique to treat the MADM problem having non-commensurable (different units of measurement) and conflicting attributes. It introduces the multi attribute ranking index based on a particular measure of closeness to the ideal/aspired solution. The obtained compromise solutions could be the base for negotiation in the decision-process, involving preferences of the decision-maker using criteria weights [23]. The VIKOR method provides a maximum group utility for the majority and a minimum individual regret for the opponent. As a result, it is considered an effective tool in the MADM to solve discrete decision problems, particularly under such environment where the decision-maker is not able, or does not know to express his/her preferences at the early stages of system design. The multi-attribute measure used in VIKOR method for compromise ranking is developed from the L_p metric, which is used as an aggregating function in the compromise programming. The classical VIKOR method present the assessment values as real numbers and consider that both the weights of decision-makers and attributes are known a priori. Wan et al. [34] extended the classical VIKOR method to MAGDM problems with fuzzy preference information captured through TIFNs.

The decision of plant location selection (PLS) is considered important for the manufacturing companies because it help in minimizing the cost and maximizing the use of resources. The PLS problem is inherently a MAGDM problem as it involves the evaluation of potential locations on many attributes namely, investment cost, availability of skilled workers, availability of acquirement material, climate, etc. [29]. It is worthy to mention that most of the existing approaches for PLS problem are based on fuzzy set theory concepts that involve only the membership degree, but neglect both the hesitation and indeterminacy that are often encountered in real-world decision-making.