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An MAGDM based on constrained FAHP and FTOPSIS and its application to supplier selection ☆

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ABSTRACT

The multiple attribute decision making (MADM) is widely used to rank alternatives with respect to multiple attributes. A new method for the multiple attribute group decision making (MAGDM) is proposed in this paper. In our method, linguistic terms are used during the whole evaluation process, the constrained fuzzy analytic hierarchy process is adopted to measure the relative importance of attributes, which is converted into the deterministic weight vector by using the extent analysis technique, the fuzzy TOPSIS is then used to rank the alternatives. With these improvements and other transformation skills, our new algorithm can better resolve the fuzzy information by decreasing its uncertain level, more scientific and accurate attribute weights can thus be obtained. More importantly, it can significantly reduce the computation amount and can provide more reasonable and robust ranking results. All these advantages are demonstrated by applying our new method to two supplier selection problems, typical complex MAGDM problems investigated extensively due to their practical importance. The sensitivity analysis and comparison with existing approaches sufficiently show the practicality, robustness and efficiency of our new algorithm, which can be applied to different kinds of complex MAGDM problems in reality.

1. Introduction

The multiple attribute decision making (MADM) is an important research area in modern decision making science. It has been widely applied in many fields such as economy, environment and management. Two typical MADM methods are the analytic hierarchy process (AHP) and the technique for order preference by similarity to an ideal solution (TOPSIS). The AHP is proposed by Saaty [1]. It has received more and more attention [2–5] since its appearance. This method is clear in structure and easy to understand. Nevertheless, it requires pairwise comparisons between attributes and alternatives in order to set up decision matrices, which result in huge computation and low accuracy. The TOPSIS is proposed by Hwang and Yoon [6]. They think that a good alternative should be the one that is nearest to the positive ideal alternative, and at the same time, is farthest from the negative ideal alternative. The TOPSIS has been studied and applied extensively [7–15]. In TOPSIS, it is necessary to assign attribute weights of alternatives to reflect their relative importance. At present, the equal weight is usually adopted for simplicity, or the attribute weights are subjectively determined, the shortcomings of these methods are obvious. In practice, different attributes have different importance, so it is not reasonable to assign them equal weights. While for the weights selected subjectively, one can hardly guarantee their objectivity and reasonability during the

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decision making process. To overcome disadvantages of these two methods, one can first determine the weights of attributes by AHP, then weight the decision matrix and rank alternatives by TOPSIS. In this way, the intensive computation required in determining decision matrices can be greatly reduced, while the weight selection difficulty in TOPSIS can be reasonably settled.

Actually, different ways to combine AHP and TOPSIS have been investigated in many papers. In these methods, the attribute weights are often determined by AHP, the alternatives are ranked by TOPSIS. For example, Lin solves the customer-driven product design problem by using AHP and TOPSIS in [16]. But in this method, the evaluations about attributes and alternatives are all supposed to be deterministic numbers. The combination of AHP and the fuzzy TOPSIS (FTOPSIS) method is applied in [17] to solve the solid waste transshipment site selection problem. In that paper, the attribute weights determined by AHP are real numbers, and the evaluations of alternatives with respect to different attributes are in linguistic terms. Similarly, the weapon selection problem is investigated in [18] by using AHP and FTOPSIS. Unlike the above papers, the fuzzy AHP (FAHP) and TOPSIS are used in [19] to evaluate Turkish cement firms, where linguistic terms are adopted to evaluate attributes and real numbers are used to evaluate alternatives. The FAHP and TOPSIS methodologies are used to evaluate hazardous waste transportation firms in [20]. Through combining above techniques, the Turkish bank sector evaluation problem is studied in [21]. Furthermore, the shopping center selection problem [22] and production system performance problem [23] are solved by combining FAHP and FTOPSIS, where both attribute and alternative evaluations are in linguistic terms.

Fuzziness and uncertainties are often encountered in practice. During the decision making process, people are often reluctant or unable to assign accurate values in the evaluation process due to the following typical reasons: the social environment is rather complex; the people thinking is usually uncertain, ambiguity and vague; the expert's knowledge might be limited. People prefer to provide their evaluations in linguistic terms. For example, one would like to use "good", "very good", "medium","bad" or "very bad" to express his/her preference in evaluating the product quality or performance. Fuzzy set theory is an effective tool to deal with the uncertainty and vagueness. It can incorporate uncertain information, incomplete information, unavailable information and partially ignorant facts in the decision model. When evaluating alternatives, the adopted linguistic terms are translated into trapezoidal fuzzy numbers or triangular fuzzy numbers. The ranking of alternatives relies on results from the fuzzy number operation. Unfortunately, usual mathematical operations might generate meaningless results when applied to fuzzy numbers, the direct unrevised application of fuzzy arithmetic could lead to questionable results, due to a deficient generalization from the real number arithmetic to the fuzzy intervals one [24]. Unique rules are got when arithmetic operations are performed on real numbers, but this principle is not valid in the fuzzy arithmetic. To overcome this problem, Klir [25] investigates fuzzy operations under constraints. By imposing requisite constraints, the uncertainty degree is reduced and relatively accurate results can be obtained. Enea and Piazza [24] apply this kind of constrained fuzzy operations to AHP. Tiryaki and Ahlatcioglu [26] study the fuzzy portfolio selection by using the constrained FAHP.

As a further improvement to existing researches, in this paper, we initially use the constrained fuzzy AHP (CFAHP) to determine the attribute weights, then rank alternatives by the FTOPSIS; meanwhile, evaluations of both attributes and alternatives are in linguistic terms. With these improvements and the simultaneous application of other skills such as the extent analysis technique, our new method can further resolve the fuzzy information by reducing its uncertain level, and can obtain more scientific and accurate attribute weights. Meanwhile, it can significantly reduce the computation complexity, and more importantly, it can provide more reasonable and robust ranking results. All these characteristics ensure that our new algorithm can efficiently solve different kinds of complex MAGDM problems in practice. We will demonstrate the above arguments one after another in the following sections.

With the development of information technology and increasing competition among companies, the supply chain management has become an important factor affecting the company competitiveness. The evaluation and selection of suppliers are critical for setting up an efficient, rapid response supply chain. There are usually many qualitative and quantitative attributes to be considered. The supplier selection problem is thus a MADM problem. On the other hand, with the business globalization, the supplier selection problem has become more and more complex. In order to choose an appropriate supplier, several decision makers from different departments in the company are often involved, so it is also a typical MAGDM problem.

Based on the fuzzy set theory, some methods have been proposed for the supplier selection problem. A hierarchy fuzzy MADM model is proposed by Chu and Lin [15], they adopt linguistic terms to assess the ratings and weights of supplier selection attributes and then use FTOPSIS to rank the suppliers. Chen et al. [27] solve the supplier selection problem by using the extended fuzzy AHP-based approach. In their paper, triangular fuzzy numbers are used to express decision makers' assessments to set up decision matrices, and the weight vectors are derived according to the fuzzy synthetic extent. Priority weights of suppliers are determined as the product of the weight of each supplier and the weight of the corresponding attribute, the suppliers are then ranked by their priority weights. Amir et al. [28] use linguistic terms to evaluate alternatives and attributes, then aggregate the evaluation values and defuzzify them, here VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) is used to rank the alternatives. Önüt et al. [29] investigate a telecommunication company selection problem in the fuzzy environment by using the analytic network process and TOPSIS.

Although many methods have been proposed to solve it, the general supplier selection problem has not been well solved due to its complexity. Until now, we have not found any research using CFAHP and FTOPSIS to solve the supplier selection problem. As an application, our new method will be applied to solve this kind of MAGDM problems.