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# An analytical solution to fuzzy TOPSIS and its application in personnel selection for knowledge-intensive enterprise

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ABSTRACT

Personnel selection is a critical enterprise strategic problem in knowledge-intensive enterprise. Fuzzy number which can be described as triangular (trapezoid) fuzzy number is an adequate way to assess the evaluation and weights for the alternatives. In that case, fuzzy TOPSIS, as a classic fuzzy multiple criteria decision making (MCDM) methods, has been applied in personnel selection problems. Currently, all the researches on this topic either apply crisp relative closeness but causing information loss, or employ fuzzy relative closeness estimate but with complicated computation to rank the alternatives. In this paper, based on Karnik–Mendel (KM) algorithm, we propose an analytical solution to fuzzy TOPSIS method. Some properties are discussed, and the computation procedure for the proposed analytical solution is given as well. Compared with the existing TOPSIS method for personnel selection problem, it obtains accurate fuzzy relative closeness instead of the crisp point or approximate fuzzy relative closeness estimate. It can both avoid information loss and keep computational efficiency in some extent. Moreover, the global picture of fuzzy relative closeness provides a way to further discuss the inner properties of fuzzy TOPSIS method. Detailed comparisons with approximate fuzzy relative closeness method are provided in personnel selection application.

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## 1. Introduction

Human resources are one of the most critical elements for knowledge-intensive enterprises to enhance their competitive strength in knowledge economy environment [25,27]. And personnel recruitment and selection directly determines the input quality of human resource [2,10]. With the variety of candidates that exist in human resource market, the employer must know which candidate matches the qualifications required to perform the defined job in the best way [12,20]. To solve this problem, more attention have been payed to the selection of eligible and adequate person among alternatives [13,26,40]. However, the factors with respect to knowledge-intensive employees are difficult to express as crisp numbers, such as technology skill, work experience, personality and oral communication skill. The fuzzy set theory proposed by Zadeh [50] and the concept of fuzzy numbers introduced by Dubois and Prade [9] can be applied to improve the evaluation and weights for these factors in personnel selection problems [8,14,17,18,28,30]. Liang and Wang [25] introduced a fuzzy decision making method to combine subjective assessments with objectives tests. Yaakob and Kawata [49] also used a fuzzy decision making method to deal with workers' placement problem.

The technique for order preference by similarity to ideal solution (TOPSIS) [15] is a classic decision making method, which is based on the idea that the best alternative should have the shortest distance from a positive ideal solution and the farthest distance from a negative ideal solution. In traditional TOPSIS method, the weights of the criteria and the ratings of alternatives are defined as crisp numbers. Fuzzy number which can be described as triangular (trapezoid) fuzzy number is an adequate way to deal with the imprecision or vagueness nature of the subjective assessments. Under this condition, Jahanshahloo et al. [16] extended the TOPSIS method to triangular fuzzy numbers environment. Wang and Lee [45] generalized the TOPSIS method with max and min operations in a fuzzy environment. Mokhtarian and Vencheh [38] revised fuzzy TOPSIS method based on the left and right scores. Peng et al. [22,39] developed fuzzy TOPSIS approach to evaluate classification algorithms for financial risk prediction. Behzadian et al. [3] conducted a state-of-the-art literature

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survey on TOPSIS applications and methodologies. Dymova [11] extended fuzzy TOPSIS method which is free of the limitations of other known approaches. Triantaphyllou and Lin [43] developed the fuzzy TOPSIS method based on fuzzy arithmetic operations, which leads a fuzzy relative closeness. Apart from the triangular (trapezoid) fuzzy environment, Chen and Tsao [7] and Ashtiani et al. [1] developed the TOPSIS method to interval-valued fuzzy numbers environment. Boran et al. [4] proposed an intuitionistic based TOPSIS method for MCDM problem. Wei [46,47] developed two fuzzy linguistic MCDM methods based on the idea of TOPSIS method. Chen and Lee [6] presented an interval type-2 fuzzy TOPSIS method to hire a system analyst.

For the application of TOPSIS method in personnel selection field, Chen [5] extended TOPSIS method to fuzzy environment for personal selection. Shih et al. [42] proposed an integrated group TOPSIS method procedure for solving personnel selection. Mahdavi et al. [35] designed a fuzzy TOPSIS model with the appropriate negations for system analyst selection. Saremi et al. [41] modified TOPSIS approach with geometric mean to select total quality management consultant. Kelemenis and Askounis [20] developed TOPSIS approach which incorporates the veto threshold for the ranking of the candidates. Dursun and Karsak [10] extended TOPSIS method to both linguistic and numerical assessment scales in personnel selection. Kelemenis et al. [21] combined TOPSIS method with fuzzy logic to solve support managers' selection problem. Wang and Elhag [44] developed a fuzzy TOPSIS method based on $\alpha$-cut sets to solve personnel selection problem, which obtains approximate fuzzy relative closeness for the alternative.

From the analysis of the researches above, it is observed that except for Triantaphyllou and Lin's [43] and Wang and Elhag's [44] TOPSIS methods, all the others mentioned above obtain a crisp relative closeness for the alternative. They defuzzify the imprecise values at the beginning of the computing process, which will bring information loss. Although Triantaphyllou and Lin's TOPSIS method and Wang and Elhag's TOPSIS method provide a fuzzy relative closeness for the alternative, the closeness obtained by Triantaphyllou and Lin's method is badly distorted or over exaggerated because of the fuzzy arithmetic operations. The closeness computed by Wang and Elhag's method is an approximate fuzzy estimate, but the accuracy is largely depended on the $\alpha$-cut granularity, and the computation of each $\alpha$-cut is repetitive. Hence, it is necessary to develop an exact fuzzy TOPSIS method to solve MCDM problems. Motivated by such a need, we develop an exact analytical solution to fuzzy TOPSIS model based on KM algorithm [19,48]. KM algorithm is originally used for computing the centroid of interval type-2 fuzzy set [19]. It transforms the fractional NLP problems into identifying the switch points of $\alpha$ levels, which is monotonically and superexponentially convergent to the optimal solution [37]. In view of the characteristic of KM algorithm, the advantage of the proposed analytical solution to fuzzy TOPSIS method can be summarized as follows. Firstly, it is computationally efficient, as the KM algorithm transforms the fractional nonlinear programming (NLP) problem into identifying the switch points of $\alpha$ level, and the computation can be merged into once when some $\alpha$-cut intervals have the same switch point. Secondly, it is accurate, as all the switch points are identified through analytical function of fuzzy TOPSIS, not artificial $\alpha$-cut level sets in discrete format. Thirdly, the analytical expression presents a global picture of fuzzy relative closeness, which provides the possibility for further discussing the inner properties of the fuzzy TOPSIS method.

This paper is organized as follows: Section 2 introduces the fuzzy TOPSIS method based on $\alpha$-cut and the principle of KM algorithm. Section 3 proposes an analytical solution to fuzzy TOPSIS method, and discusses some properties of it. Section 4 illustrates an application of personnel selection in a software enterprise, and compares the results with that of $\alpha$-cut method. Section 5 summarizes the main results and draws conclusions.

## 2. Preliminaries

In this section, we introduce the computation procedure of fuzzy TOPSIS with $\alpha$-cut sets and the principle of KM algorithm.

### 2.1. The computation of fuzzy TOPSIS with $\alpha$-cut sets

A fuzzy number is a convex fuzzy set, which is characterized by an interval [0, 1]. Take the triangular fuzzy number $\tilde{A} = (a, b, d)$ as an example, whose membership functions are defined as follows.

$$\mu_{\tilde{A}}(x) = \begin{cases} (x-a)/(b-a), & x \in [a, b], \\ (d-x)/(d-b), & x \in [b, d], \\ 0, & \text{otherwise.} \end{cases}$$

According to Zadeh's extension principle [50], the fuzzy set $\tilde{A}$ can be denoted by its intervals as:

$$\tilde{A} = \bigcup_{\alpha} \alpha \cdot A_{\alpha}, \quad \alpha \in [0, 1],$$

where $A_\alpha$ is a $\alpha$-cut set of fuzzy number $\tilde{A}$, and

$$\begin{aligned} A_\alpha &= \{\tilde{x} \in \tilde{X} \mid \mu_{\tilde{A}}(\tilde{x}) \geq \alpha\}, \\ &= [\min\{\tilde{x} \in \tilde{X} \mid \mu_{\tilde{A}}(\tilde{x}) \geq \alpha\}, \max\{\tilde{x} \in \tilde{X} \mid \mu_{\tilde{A}}(\tilde{x}) \geq \alpha\}], \\ &= [A_\alpha^L, A_\alpha^U]. \end{aligned}$$

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