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Evaluating teaching performance based on fuzzy AHP and comprehensive evaluation approach

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ABSTRACT

Evaluating teaching performance is a main means to improve teaching quality and can plays an important role in strengthening the management of higher education institutions. In this paper, we present a novel framework for teaching performance evaluation based on the combination of fuzzy AHP and fuzzy comprehensive evaluation method. Specifically, after determining the factors and sub-factors, the teaching performance index system was established. In the index system, the factor and sub-factor weights were then estimated by the extent analysis fuzzy AHP method. Employing the fuzzy AHP method in group decision-making can facilitate a consensus of decision-makers and reduce uncertainty. On the basis of the system, the fuzzy comprehensive evaluation method was employed to evaluate teaching performance. A case application was also used to illustrate the proposed framework. The application of this framework can make the evaluation results more scientific, accurate, and objective. It is expected that this work may serve as an assistance tool for managers of higher education institutions in improving the educational quality level.

1. Introduction

To improve their competitiveness level in the higher education system, universities need to provide their best services to meet the social demands. Good service can enhance the satisfaction level of students and graduates, and can attract more prospective students. A university can only provide the best service to the community if it commits to continuous quality improvement [1]. Many universities have committed to ongoing improvement and thus must evaluate the activities and services they provide. Teaching is always one of the major tasks of all universities. Therefore, quality teaching should always be one of the primary objectives for higher education institutions, and consequently, there is a need to evaluate teaching performance. The aims of evaluating teaching performance are to develop each lecturer's professionalism, to encourage self-improvement, and to maintain achievements. Evaluating teaching performance is not an easy task, as it involves human decision-making, which is imprecise, vague, and uncertain. Hence, using a scientific method to evaluate teaching performance comprehensively and effectively plays a crucial role in determining the quality of the teaching performance.

In recent years, several researchers have focused on evaluating teaching performance in universities. He et al. [2] presented an approach for teaching performance evaluation based on the analytic hierarchy process (AHP). The results of the evaluation can reflect the teaching quality more objectively. Dong and Dai [3] combined fuzzy and neuron network to evaluate teaching quality. They used historical data as a standard indicator to train the neuron network. The combined method has been a good application of fuzzy theory in evaluating teaching performance. Ramli et al. [4] proposed an approach of teaching performance evaluation with outlier data using fuzzy approach. Their method provided an accurate evaluation of teaching performance. The studies we examined all provide good applications of mathematical models in performance evaluations. However, these studies did not give adequate consideration to the design of a scientific evaluation index system. Apart from aforementioned studies, most of the other related research concentrated on strategies and theories of teaching performance evaluation, while few were devoted to the quantitative analysis of the evaluation index system.

Since we realize that the key to evaluation process is to design the evaluation index system, our study concentrates on the establishment of a teaching performance evaluation index system with reasonable and objective factor weights. Determining the weight of a factor is related to the multiple-criteria decision-making problem, and the decision-makers usually feel more confident giving linguistic variables rather than expressing their judgments in the form of numeric values. Hence, fuzzy set theory is a useful tool to deal with imprecise and uncertain data. While, AHP, proposed by Satty [5], is a practical decision-making method. Being an extension of AHP, fuzzy AHP is able to solve the hierarchical fuzzy decision-making problems. The fuzzy AHP method has been widely used by various researchers to solve different decision-making problems. Mikhailov and Tsvetinov [6] used fuzzy AHP to deal with the uncertainty and imprecision of the service evaluation process. Gungor et al. [7] proposed a personnel selection system based on fuzzy AHP that evaluated the best and most adequate personnel dealing with the rating of both qualitative and quantitative criteria. Chou et al. [8] employed fuzzy AHP to evaluate the weighting for each criterion in human resource for science and technology. Fuzzy AHP has been also used to combine with other techniques to solve real-life decision-making problems. A combination of fuzzy AHP and fuzzy Kano was proposed to optimize product varieties for smart cameras [9]. In the study, fuzzy AHP was efficient to extract customer preferences for core attributes associated with multiple levels of specification when a product is functionally characterized.

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Taylana et al. [10] utilized fuzzy AHP and fuzzy TOPSIS to evaluate the construction projects and their overall risks under incomplete and uncertain situations. In their work, fuzzy AHP was used to create favorable weights for the fuzzy linguistic variable of construction projects overall risk. These studies revealed the high applicability of fuzzy AHP for solving practical problems. Therefore, fuzzy AHP is appropriate for determining the weights in the performance evaluation index system. In our study, in order to evaluate teaching performance, a novel framework based on the combination of fuzzy AHP and fuzzy comprehensive evaluation method is proposed. Specifically, Chang's extent analysis fuzzy AHP method [11,12] is utilized to obtain the factor and sub-factor weights of a teaching performance evaluation index system. On the basis of the system, the fuzzy comprehensive evaluation can be applied to evaluate teaching performance.

The remainder of this paper is organized as follows: Section 2 presents the Chang's fuzzy AHP method and some related concepts. Section 3 then discusses the framework for designing the evaluation index system. Section 4 deals with establishing the teaching performance evaluation index system and determining the factor and sub-factors weights. Section 5 presents an application of the proposed evaluation index system based on the comprehensive evaluation method; and finally, conclusions are then given in Section 6.

2. Fuzzy analytic hierarchy process

2.1. Fuzzy sets and fuzzy numbers

Fuzzy set theory [13] was first introduced to deal with the uncertainty due to imprecision or vagueness. A fuzzy set $\tilde{A} = \{(x, \mu_{\tilde{A}}(x))|x \in X\}$ is a set of ordered pairs and X is a subset of the real numbers R, where $\mu_{\tilde{A}}(x)$ is called the membership function which assigns to each object x a grade of membership ranging from zero to one. Since its introduction, fuzzy set theory has been widely applied to address real-world problems in which decision-makers need to analyze and process information that is imprecise. A fuzzy number is a special case of a convex normalized fuzzy set. It is possible to use different fuzzy numbers under various particular situations. Triangular and trapezoidal fuzzy numbers are usually adopted to deal with the vagueness of decisions related to the performance levels of alternative choices with respect to each criterion. When the two most promising values of a trapezoidal fuzzy number are the same number, it becomes a TFN. This means that a TFN is a special case of a trapezoidal fuzzy number. Because of its intuitive appeal and computational efficiency, the TFN is the most widely used membership function for many applications. TFNs are usually employed to capture the vagueness of the parameters related to the decision-making process. In order to reflect the fuzziness which surrounds the decision-makers when they conduct a pairwise comparison matrix, TFN is expressed with boundaries instead of crisp numbers. A triangular fuzzy number, denoted as $\tilde{A} = (l, m, u)$, has the following membership function:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x-l}{m-l} & \text{for } \ l \le x \le m \\ \dfrac{u-x}{u-m} & \text{for } \ m \le x \le u \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

A triangular fuzzy number $\tilde{A}$ is shown in Fig. 1. The parameter "m" is the most promising value. The parameters "l" and "u", respectively, are the smallest possible value and the largest possible value; they limit the field of possible evaluation. When $l = m = u$, the triangular fuzzy number becomes a non-fuzzy number. The triplet (l, m, u) can be used to describe a fuzzy event.

Consider two TFNs $\tilde{A}_1$ and $\tilde{A}_2$, $\tilde{A}_1 = (l_1, m_1, u_1)$ and $\tilde{A}_2 = (l_2, m_2, u_2)$. The main operational laws [14] for two triangular fuzzy numbers $\tilde{A}_1$ and $\tilde{A}_2$ are as follows:

$$\tilde{A}_1 \oplus \tilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{2}$$

$$\tilde{A}_1 \otimes \tilde{A}_2 \approx (l_1 l_2, m_1 m_2, u_1 u_2), \quad \text{for} \quad l_i > 0, m_i > 0, u_i > 0, \quad i = 1, 2 \tag{3}$$

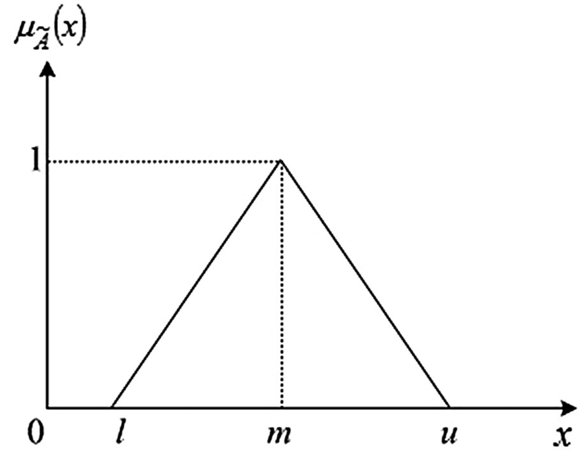

Fig. 1. A triangular fuzzy number, $\tilde{A} = (l, m, u)$.

$$\tilde{A}_1 / \tilde{A}_2 = (l_1/u_2, m_1/m_2, u_1/l_2), \quad \text{for} \quad l_i > 0, m_i > 0, u_i > 0, \quad i = 1, 2 \tag{4}$$

$$\tilde{A}_1^{-1} \approx (1/u_1, 1/m_1, 1/l_1), \quad \text{for} \ \ l_1 > 0, m_1 > 0, u_1 > 0 \tag{5}$$

2.2. The extent analysis fuzzy AHP method

There are several fuzzy AHP methods reported in the literature. Buyukozkan et al. [15] gave a comparison of different fuzzy AHP methods. The comparison included the advantages and disadvantages of each method. Among different AHP methods, Chang's method [11,12] has been widely used in different application areas, such as supplier selection problems [16]. This method uses linguistic variables to express the comparative judgments made by different makers. It requires lower computation complexity than the other methods when implementing. In this study, we employed this method to get the factor and sub-factor weights from expert's opinion as making pairwise comparisons.

Let $\tilde{A} = (\tilde{a}_{ij})_{n \times m}$ be a fuzzy pairwise comparison matrix, where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$. The steps of the Chang's method can be described as follows:

Initially, the value of the fuzzy synthetic extent with respect to the ith object is defined as:

$$S_i = \sum_{j=1}^{m} M_{ij} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} \right]^{-1}, \tag{6}$$

with

$$\sum_{j=1}^{m} M_{ij} = \left(\sum_{j=1}^{m} l_{ij}, \sum_{j=1}^{m} m_{ij}, \sum_{j=1}^{m} u_{ij} \right), \quad i = 1, 2, \ldots, n \tag{7}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij} = \left(\sum_{i=1}^{n} \sum_{j=1}^{m} l_{ij}, \sum_{i=1}^{n} \sum_{j=1}^{m} m_{ij}, \sum_{i=1}^{n} \sum_{j=1}^{m} u_{ij} \right) \tag{8}$$

$$\left[\sum_{i=1}^{N} \sum_{j=1}^{m} M_{ij} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} u_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} m_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} l_{ij}} \right) \tag{9}$$

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