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Evaluating the criteria for human resource for science and technology (HRST) based on an integrated fuzzy AHP and fuzzy DEMATEL approach

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ABSTRACT

This study intends to use a combination of fuzzy Analytic Hierarchy Process (AHP) and fuzzy Decision-making Trial and Evaluation Laboratory (DEMATEL) method in human resource for science and technology (HRST). Specifically, this study first uses AHP to evaluate the weighting for each criterion and then use DEMATEL method to establish contextual relationships among those criteria. We find out Infrastructure might be more critical since it is a cause and will directly influence human resource for science and technology performance. For human resource for science and technology (HRST), improving Infrastructure might be a better choice for the long period of time. Moreover, Education, R&D Expenses and Immediate output are more important second-tier criteria than Value, Cooperation, Labor Market, Human Capital and Intermediate output. Therefore, the improvement should be started with Infrastructure, particularly on identification of the Education, R&D Expenses and Immediate output.

1. Introduction

To build a sustainable national competitive advantage based on science and technology and the skilled workers. Although traditional analysis of national competitiveness can display a country's overall competitive advantages, it is unable to highlight the national competitive advantage derived from the technology application. The science and technology are competition advantage that derives from human talent. The human resource for science and technology (HRST) are the crucial survival and growth factor for economics. The human resource competitiveness is the most important factor in achieving economic competitiveness. Therefore, evaluating the performance of HRST in each country is the critical research topic. This study intends to use a combination of fuzzy Analytic Hierarchy Process (AHP) and fuzzy Decision-making Trial and Evaluation Laboratory (DEMATEL) method in human resource for science and technology (HRST). Specifically, this study uses AHP to evaluate the weighting for each criterion and then use DEMATEL method to establish contextual relationships among those criteria.

The reminder of this paper is organized as follows. Sections 2 and 3 present how we adopt the methodology, fuzzy AHP and fuzzy DEMATEL in real world. Section 4 displays our empirical results along with some discussions relating to managerial implications. Finally conclusions and remarks are then given in Section 5.

2. Fuzzy Analytic Hierarchy Process (FAHP) method

Analytic Hierarchy Process (AHP) is a powerful method to solve complex decision problems. Any complex problem can be decomposed into several sub-problems using AHP in terms of hierarchical levels where each level represents a set of criteria or attributes relative to each sub-problem. The AHP method is a multi-criteria method of analysis based on an additive weighting process, in which several relevant attributes are represented through their relative importance. Through AHP, the importance of several attributes is obtained from a process of paired comparison, in which the relevance of the attributes or categories of drivers of intangible assets are matched two-on-two in a hierarchic structure.

However, the pure AHP model has some shortcomings [23]. They pointed out that the AHP method is mainly used in nearly crisp-information decision applications; the AHP method creates and deals with a very unbalanced scale of judgment; the AHP method does not take into account the uncertainty associated with the mapping of human judgment to a number by natural language; the ranking of the AHP method is rather imprecise; and the subjective judgment by perception, evaluation, improvement and selection based on preference of decision-makers have great influence on the AHP results [27]. To overcome these problems, several researchers integrate fuzzy theory with AHP to improve

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the uncertainty. Hence, Buckley [2] used the evolutionary algorithm to calculate the weights with the trapezoidal fuzzy numbers. The fuzzy AHP based on the fuzzy interval arithmetic with triangular fuzzy numbers and confidence index α with interval mean approach to determine the weights for evaluative elements [28].

2.1. Building the evaluation hierarchy systems for evaluating the performance of human resource for science and technology performance

This research tries to evaluating the performance human resource for science and technology performance. After reviewing the related literature, we set criteria that building the evaluation hierarchy systems.

2.2. Determining the evaluation dimensions weights

This research employs Fuzzy AHP to fuzzify hierarchical analysis by allowing fuzzy numbers for the pair-wise comparisons and find the fuzzy preference-weights. In this section, we briefly review concepts for fuzzy hierarchical evaluation. Then the following sections will introduce the computational process about Fuzzy AHP in detail.

(1) Establishing fuzzy number

Fuzzy sets are sets whose elements have degrees of membership. Fuzzy sets have been introduced by Zadeh [24] as an extension of the classical notion of set. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition – an element either belongs or does not belong to the set [14,21]. The mathematics concept borrowed from Hsieh et al. [9], Liou et al. [14].

A fuzzy number $\tilde{A}$ on $\mathbb{R}$ to be a *TFN* if its membership function $\mu_{\tilde{A}}(x) : \mathbb{R} \to [0, 1]$ is equal to following Eq. (1):

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

From the above Eq. (1), l and u mean the lower and upper bounds of the fuzzy number $\tilde{A}$, and m is the modal value for $\tilde{A}$. The *TFN* can be denoted by $\tilde{A} = (l, m, u)$. The operational laws of *TFN* $\tilde{A}_1 = (l_1, m_1, u_1)$ and $\tilde{A}_2 = (l_2, m_2, u_2)$ are displayed as following Eqs. (2)–(6).

Addition of the fuzzy number $\oplus$

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

Multiplication of the fuzzy number $\otimes$

$$\begin{aligned} \tilde{A}_1 \otimes \tilde{A}_2 &= (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) \\ &= (l_1 l_2, m_1 m_2, u_1 u_2) \\ &\quad \text{for } \; l_1, l_2 > 0; \quad m_1, m_2 > 0; \quad u_1, u_2 > 0 \end{aligned} \tag{3}$$

Subtraction of the fuzzy number Θ

$$\tilde{A}_1 \Theta \tilde{A}_2 = (l_1, m_1, u_1) \Theta (l_2, m_2, u_2) = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \tag{4}$$

Division of a fuzzy number $\varnothing$

$$\tilde{A}_1 \varnothing \tilde{A}_2 = (l_1, m_1, u_1) \varnothing (l_2, m_2, u_2) = (l_1/u_2, m_1/m_2, u_1/l_2) \quad \text{for } \; l_1, l_2 > 0; \quad m_1, m_2 > 0; \quad u_1, u_2 > 0 \tag{5}$$

Table 1
Membership function of linguistic scale (example).

Fuzzy number	Linguistic	Scale of fuzzy number
9	Perfect	(8,9,10)
8	Absolute	(7,8,9)
7	Very good	(6,7,8)
6	Fairly good	(5,6,7)
5	Good	(4,5,6)
4	Preferable	(3,4,5)
3	Not bad	(2,3,4)
2	Weak advantage	(1,2,3)
1	Equal	(1,1,1)

Reciprocal of the fuzzy number

$$\tilde{A}^{-1} = (l_1, m_1, u_1)^{-1} = (1/u_1, 1/m_1, 1/l_1) \quad \text{for } \; l_1, l_2 > 0; \quad m_1, m_2 > 0; \quad u_1, u_2 > 0 \tag{6}$$

(2) Determining the linguistic variables

Linguistic variables take on values defined in its term set: its set of linguistic terms. Linguistic terms are subjective categories for the linguistic variable. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language [25,26]. Here, we use this kind of expression to compare two building evaluation dimension by nine basic linguistic terms, as "Perfect," "Absolute," "Very good," "Fairly good," "Good," "Preferable," "Not Bad," "Weak advantage" and "Equal" with respect to a fuzzy nine level scale. In this paper, the computational technique is based on the following fuzzy numbers defined by Gumus [8] in Table 1. Here each membership function (scale of fuzzy number) is defined by three parameters of the symmetric triangular fuzzy number, the left point, middle point and right point of the range over which the function is defined.

(3) Fuzzy AHP

Then we will briefly introduce that how to carry out the fuzzy AHP in the following sections.

Step 1: Construct pair-wise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pair-wise comparisons by asking which is the more important of each two dimensions, as following matrix $\tilde{A}$

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \tag{7}$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{9}^{-1}, \tilde{8}^{-1}, \tilde{7}^{-1}, \tilde{6}^{-1}, \tilde{5}^{-1}, \tilde{4}^{-1}, \tilde{3}^{-1}, \tilde{2}^{-1}, \tilde{1}^{-1}, \tilde{1}, \tilde{2}, \tilde{3}, \tilde{4}, \tilde{5}, \tilde{6}, \tilde{7}, \tilde{8}, \tilde{9}, & i \neq j \\ 1, & i = j \end{cases}$$

Step 2: To use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion by Hsieh et al. [9].

$$\begin{aligned} \tilde{r}_i &= (\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{ij} \otimes \cdots \otimes \tilde{a}_{in})^{1/n} \\ \tilde{w}_i &= \tilde{r}_i \otimes [\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_i \oplus \cdots \oplus \tilde{r}_n]^{-1} \end{aligned} \tag{8}$$

where $\tilde{a}_{ij}$ is fuzzy comparison value of dimension i to criterion j, thus, $\tilde{r}_i$ is a geometric mean of fuzzy comparison value of criterion i to each criterion, $\tilde{w}_i$ is the fuzzy weight of the ith criterion, can be indicated by a *TFN*, $\tilde{w}_i = (lw_i, mw_i, uw_i)$. The lw_i, mw_i and uw_i stand for the lower, middle and upper values of the fuzzy weight of the ith dimension.