

ORIGINAL RESEARCH PAPER

Fuzzy Multi-criteria decision making approach for human capital evaluation of municipal districts

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ABSTRACT: People in every organization could be considered as the most important resource which contributes to the development of that organization. In fact, human capital is the most important dimension of organization's intellectual capital especially in service-oriented organizations like municipality. Therefore, the main purpose of this paper is to introduce a suitable framework for human capital evaluation of different municipal districts. This framework consists of three steps. First, the main human capital components and their related indicators are determined through literature survey. Then the relative importance of these components is calculated based on experts' judgments. Finally, organizations are ranked in terms of human capital components and their relevant indicators. TOPSIS, A well-known multi-criteria decision-making method was used for ranking alternative municipal districts based on the weighted HC criteria. A fuzzy approach was integrated with this method to make up the vagueness of decision-makers' judgments. The applicability of the proposed framework was demonstrated by a numerical example.

KEYWORDS: *Fuzzy; Human capital (HC); Multi-criteria decision-making; Municipality; TOPSIS*

INTRODUCTION

Two main sets of value have been recognized for organizations: financial value and intellectual capital value. The latter set is divided into human, structural, and relational capital values (Guerrero-Baena *et al.*, 2015). Human capital (HC) is an important construct in many disciplinary fields from macro scholarship in economics to micro level scholarship in psychology (Boon *et al.*, 2018). It is considered the most important sub-dimension of the IC which exist in entirely all IC conceptual frameworks (Bontis *et al.*, 2000; Bozbura *et al.*, 2007). Many indicators for HC definition and measurement have been recognized by authors. They

include variety of components such as employee education (Abeysekera and Guthrie, 2004; Bozbura and Beskese, 2007; Campbell and Abdul Rahman, 2010; Shih *et al.*, 2010), work related knowledge (Baxter and Matear, 2004; Mehralian *et al.*, 2013), HR activities (Tai and Chen, 2009; Calabrese *et al.*, 2013) and employee attitude (Mehralian *et al.*, 2013; Campbell and Abdul Rahman, 2010). Surveying the related literature shows that the plurality and diversity of HC indicators make the authors invited to classify and select the most appropriate indicators. Therefore, the first step to measure the HC capability of different organizations is to construct a framework for HC components and their related indicators through a comprehensive survey of

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the literature. In addition, prioritization of these indicators helps focus and weight more on the most important ones. Thus, this step is considered as the second phase of the study. After selecting the most relevant HC indicators and weighting them, it will be feasible to rank our alternative organizations (municipal districts) based on them. Therefore, ranking alternatives is considered as the last step of the study. Because of abstract, intangible, and difficult to measure nature of HC concepts and the qualitative expert judgments in this process, fuzzy approach is used to capture and foster HC dynamics. Therefore, experts and managers are supported by the use of linguistic variables in the evaluation process of the company intangible assets.

This paper is organized as follows: First the literature about key HC components and their related indicators were presented. Then the research method and the definition and procedure of the fuzzy TOPSIS method were introduced. In order to demonstrate the applicability of the proposed framework a numerical example were applied in the next section. The relative weights of HC components are calculated through integrating expert judgments and the three municipal districts are ranked based on their HC capability through FTOPSIS technique. Finally the application results and offer recommendations for future researches were discussed.

Measuring Human Capital

The company value contains not only financial capital but also intellectual capital. Financial capital represents the organization's book value and the value of its financial and physical assets. Also, intellectual capital is considered as assets created through intellectual activities ranging from acquiring new knowledge to creating valuable relationships (Chen and Tai, 2005). One of the most extended categorizations for IC is introduced by Brooking (1997): Customer capital which give the company power in the marketplace such as trademarks and customer loyalty; Innovation capital representing property of the mind-intellectual property such as patents and trademarks; Process capital which gives the organization internal strength such as corporate culture and strength derived from IT systems, and finally Human capital derived from the people who work in the organization, such as their knowledge,

competencies, networking capabilities and so on. As human capital could be considered as the core competency of service organizations like municipality, the focus of this study is on this part.

In order to measure HC capability of an organization, several component and indicators have been introduced by scholars. Table 1 shows the most repeated ones which shape the conceptual framework of this study. It worth saying that HC indicators are not limited to these ones, but the most repeated and common HC indicators were selected.

MATERIALS AND METHODS

The analytical framework of this research is illustrated in Fig. 1. According to it, the main purpose of the study is developing a human capital evaluating model in order to assess and compare the HC capability of municipal districts. In this regard by studying the literature related to intangible capitals, the main HC categories, was recognized. These are the framework criteria and include five main indicators which shown in Table 1 (C_1 : Education, C_2 : Work Related Knowledge, C_3 : Employee Skills, C_4 : Employee Attitude and C_5 : HR Activities). Then the weights of each HC criterion was calculated. Finally, according to these weights, the FTOPSIS method was applied for the purpose of ranking three different municipal districts as the alternatives (A_1 , A_2 and A_3).

A brief review on the concepts of the fuzzy logic and linguistic variables and details of the required Multi-criteria Decision Making (MCDM) analytical methods are explained in the following subsections.

The Fuzzy logic and linguistic variables

Fuzzy set theory, which was introduced by Zadeh (1965) to deal with problems in which a source of vagueness is involved, has been utilized for incorporating imprecise data into the decision framework. A fuzzy set \bar{A} can be defined mathematically by a membership function $\mu_{\bar{A}}(X)$, which assigns each element x in the universe of discourse X a real number in the interval $[0, 1]$. A triangular fuzzy number can be defined by a triplet (a, b, c). The membership function is defined as Eq. 1

$$\mu_{\bar{A}}(x) = \begin{cases} \frac{x-a}{b-a} & a \leq x \leq b \\ \frac{x-c}{b-c} & b \leq x \leq c \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

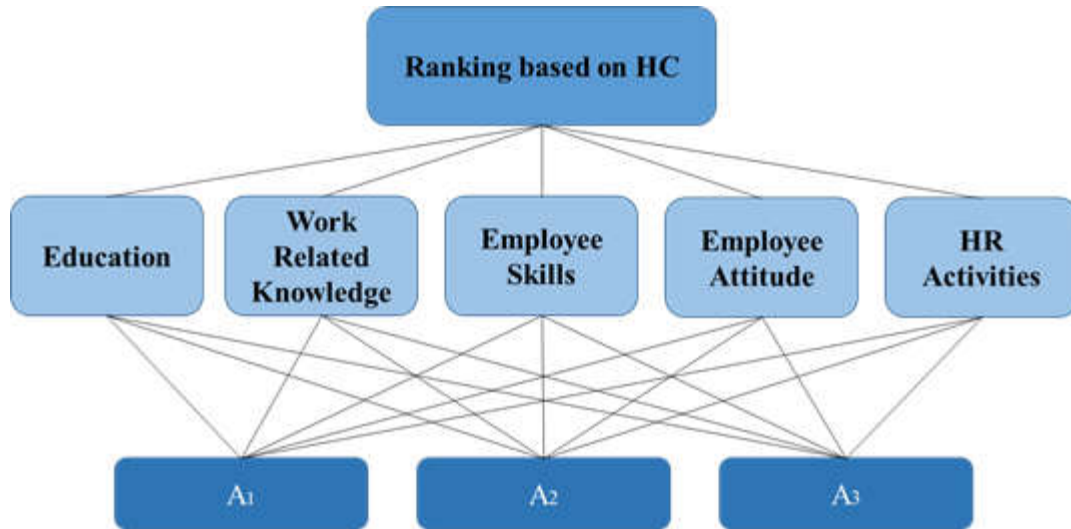


Fig. 1: The conceptual framework consists of goal, criteria and alternatives

Table 1: Indicators of human capital

| HC Indicators | Referances |
|--|--|
| 1. Education (University degree, Professional qualification) | Abeysekera and Guthrie (2004); Bozbura and Beskese (2007); Shih, <i>et al.</i> , (2010); Campbell and Abdul Rahman (2010); Mehralian <i>et al.</i> , (2013) |
| 2. Work Related Knowledge (Know how, Work related Experience, Seniority) | Abeysekera and Guthrie (2004); Baxter and Matear (2004); Bozbura and Beskese (2007); Shih <i>et al.</i> , (2010); Campbell and Abdul Rahman (2010); Mehralian <i>et al.</i> , (2013) |
| 3. Employee Skills (Technical/ Professional skills, Teamwork skills, Problem solving skills, Communication skills) | Bontis (1998); Baxter and Matear (2004); Bozbura (2004); Bozbura, Beskese <i>et al.</i> , Abeysekera and Guthrie (2004); Bontis <i>et al.</i> , (2000); (2007); Shih <i>et al.</i> , (2010); Campbell and Abdul Rahman (2010); Suraj and Bontis (2012); Mehralian <i>et al.</i> (2013) |
| 4. Employee Attitude (Employee satisfaction, Being ethical, Enthusiasm for working with org., Commitment, Emotional stability, Conscientiousness) | Bontis (1998); Bontis <i>et al.</i> , (2000); Bozbura (2004); Baxter and Matear (2004); Bozbura <i>et al.</i> , (2007); Shih <i>et al.</i> , (2010); Campbell and Abdul Rahman (2010); Suraj and Bontis (2012); Mehralian <i>et al.</i> , (2013) |
| 5. HR Activities (Recruitment programs, Employee retention Training programs, Career development, Employee compensation) | Bontis (1998); Bontis <i>et al.</i> , (2000); Bozbura (2004); Abeysekera and Guthrie (2004); Bozbura <i>et al.</i> , (2007); Tai and Chen (2009); Suraj and Bontis (2012); Campbell and Abdul Rahman (2010); Mehralian <i>et al.</i> , (2013); Calabrese <i>et al.</i> , (2013) |

Triangular fuzzy numbers are appropriate for quantifying the vague information about most decision problems. The primary reason for using triangular fuzzy numbers is their intuitive and computational-efficient representation (Karsak, 2002). A linguistic variable is defined as a variable which values are not numbers, but words or sentences in natural or artificial language. The concept of a linguistic variable appears as a useful means for providing an approximate characterization of phenomena that are too complex or ill-defined to be described in conventional quantitative terms (Zadeh, 1975). Table 2 shows the Linguistic variables and their respected fuzzy numbers which are used in this study.

Fuzzy TOPSIS

TOPSIS analyses an MCDM problem with m alternatives in the n -dimensional space. The method is based on the concept that the best alternative should have the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal solution. In TOPSIS method, an index which is called “similarity” is defined which measures the closeness to the positive-ideal solution and the remoteness from the negative ideal solution. Then an alternative with the maximum

similarity to the positive-ideal solution is selected (Wang et al., 2007). It is often difficult for a decision-maker to assign a precise performance rating to an alternative based on the related criteria. The benefit of using a fuzzy approach is helping assign the relative importance of alternatives using fuzzy numbers instead of crisp numbers. This method is particularly suitable for solving the group decision-making problems. The process is explained as follow (Wang et al., 2007).

Step 1: Construct the fuzzy decision matrix and choose the appropriate linguistic variables for the alternatives with respect to criteria Eq. 2:

$$\tilde{D} = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_M \end{matrix} \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix} \quad (2)$$

$$i=1,2,\dots,m; j=1,2,\dots,n$$

$$\tilde{x}_{ij} = \frac{1}{k} (\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \dots + \tilde{x}_{ij}^k)$$

In where \tilde{x}_{ij}^k is the rating of alternative A_i with respect to criterion C_j evaluated by experts.

Table 2: Linguistic variables and their respected fuzzy numbers (Wang and Wu, 2016)

| Linguistic variables | | Corresponding triangular fuzzy number |
|---|---|---------------------------------------|
| Evaluating the relative importance of HC indicators | Evaluating alternative municipal districts based on HC indicators | |
| Very low (VL) | Very poor (VP) | (1,1,3) |
| Low (L) | Poor (P) | (1,3,5) |
| Moderate (M) | Fair (F) | (3,5,7) |
| High (H) | Good (G) | (5,7,9) |
| Very high (VH) | Very good (VG) | (7,9,9) |

Step 2: Normalize the fuzzy decision matrix The normalized fuzzy decision matrix denoted by \tilde{R} is shown in Eq. 3:

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, i=1,2,\dots,m; j=1,2,\dots,n \quad (3)$$

Then the normalization process can be performed by Eq. 4:

$$\text{Where } \tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right) \quad c_j^+ = \max_i c_{ij} \quad (4)$$

The normalized \tilde{r}_{ij} are still triangular fuzzy numbers. For trapezoidal fuzzy numbers, the normalization process can be conducted in the same way. The weighted fuzzy normalized decision matrix is shown as following matrix \tilde{v} Eq. 5:

$$\tilde{v} = [\tilde{v}_{ij}]_{m \times n}, i=1,2,\dots,m; j=1,2,\dots,n \quad (5)$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \quad \tilde{w}_j$$

Step 3: Determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS)

According to the weighted normalized fuzzy decision matrix, the elements are normalized positive TFNs and their ranges belong to the closed interval [0, 1]. Then, it can be defined that the FPIS and FNIS Eq. 6:

$$\begin{aligned} A^+ &= (\tilde{V}_1^+, \tilde{V}_2^+, \dots, \tilde{V}_n^+) \\ A^- &= (\tilde{V}_1^-, \tilde{V}_2^-, \dots, \tilde{V}_n^-) \end{aligned} \quad (6)$$

$$\text{where } \tilde{V}_j^+ = (1,1,1) \text{ and } \tilde{V}_j^- = (0,0,0) \quad j=1,2,\dots,n$$

Step 4: Calculate the distance of each alternative from FPIS and FNIS The distances (d_i^+ and d_i^-) of each alternative A^+ from and A^- can be currently calculated by the area compensation method Eq. 7:

$$\begin{aligned} d_i^+ &= \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{V}_j^+), i=1,2,\dots,m \quad j=1,2,\dots,n \\ d_i^- &= \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{V}_j^-), i=1,2,\dots,m \quad j=1,2,\dots,n \end{aligned} \quad (7)$$

Step 5: Obtain the closeness coefficient and rank the order of alternatives

The CC_i is defined to determine the ranking order of all alternatives once the d_i^+ and d_i^- of each alternative have

been calculated. Calculate similarities to ideal solution. This step solves the similarities to an ideal solution Eq. 8:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad i=1, 2, \dots, m \quad (8)$$

According to the CC_i , we can determine the ranking order of all alternatives and select the best one from among a set of feasible alternatives.

Numerical example

For better understanding the method, a case study have been demonstrated in order to illustrate the applicability of the proposed method. Suppose that Tehran municipality intends to rank three of its districts based on five HC indicators. A group of decision makers consist of three experts from human resource department has been formed to assess the importance of these criteria and rank the alternatives based on them. The procedure of the proposed method for ranking municipal districts (alternatives) based on the five HC criteria is described as below:

The three experts assigned subjective weights to the five criteria according to their perceived importance. These weights are expressed based on linguistic variables whose values are shown in first column of Table 2. The weights assigned by the three experts (E_1 , E_2 and E_3) are given in Table 3 and the last column shows the geometric mean of them. According to Table 3, C_4 (employee attitudes) weight more than the other criteria in assessing the HC capability of municipal districts.

Then the experts compare three municipal districts (alternatives) based on the five HC criteria according to the linguistic variables shown in second column of Table 2. The related weighted normalized decision matrix is shown in Table 4. The last two rows of this table shows the positive and the negative ideal solutions.

Closeness Coefficient of each alternative is calculated using the PIS and the NIS. Closeness Coefficient and rankings are shown in Table 5.

According to Table 5, the third municipal district has the best HC capability in comparison with two other districts.

Table 3: The fuzzy weighting of HC* indicators

| HC. Criteria | E** ₁ | E ₂ | E ₃ | w _j *** |
|--------------------|------------------|----------------|----------------|--------------------|
| C**** ₁ | Moderate | Moderate | High | (3.55,5.59,7.61) |
| C ₂ | High | Moderate | High | (4.21,6.25,8.27) |
| C ₃ | Very high | Moderate | Moderate | (3.97,6.08,7.61) |
| C ₄ | High | Very high | High | (5.59,7.61,9.00) |
| C ₅ | High | High | Moderate | (4.21,6.25,8.27) |

* Human Capital
 ** Expert
 *** Weight
 **** Criteria

Table 4: Weighted normalized decision matrix

| | C* ₁ | C ₂ | C ₃ | C ₄ | C ₅ |
|------------------|------------------|------------------|------------------|------------------|------------------|
| A** ₁ | (0.21,0.53,0.88) | (0.15,0.46,0.89) | (0.07,0.24,0.60) | (0.17,0.47,0.82) | (0.11,0.40,0.80) |
| A ₂ | (0.15,0.46,0.89) | (0.22,0.54,1.00) | (0.16,0.48,0.89) | (0.24,0.56,0.92) | (0.24,0.56,1.00) |
| A ₃ | (0.22,0.54,1.00) | (0.22,0.54,1.00) | (0.22,0.57,1.00) | (0.29,0.62,1.00) | (0.24,0.56,1.00) |
| PIS*** | (0.22,0.54,1.00) | (0.22,0.54,1.00) | (0.22,0.57,1.00) | (0.29,0.62,1.00) | (0.24,0.56,1.00) |
| NIS**** | (0.15,0.46,0.88) | (0.15,0.46,0.89) | (0.07,0.24,0.60) | (0.17,0.47,0.82) | (0.11,0.40,0.80) |

Table 5: Closeness coefficients and rankings

| | d-* | d-** | CC*** | Rank |
|--------------------|------|------|-------|------|
| A**** ₁ | 0.91 | 0.10 | 0.10 | 3 |
| A ₂ | 0.25 | 0.66 | 0.72 | 2 |
| A ₃ | 0.00 | 0.90 | 1.00 | 1 |

* Distance from Positive-ideal solution
 ** Distance from negative-ideal solution
 *** Closeness coefficient
 **** Alternative

RESULTS AND DISCUSSION

In the present study a framework for ranking municipal districts was introduced. This framework consists of three main steps. First, the main HC criteria should be determined.

These criteria exist in the related literature and the most repeated ones are shown in [Table 1](#). It is worth saying that each company could determine its own sub-criteria for these main HC criteria. For example, HR activities are not limited to that one presented in [Table 1](#). Organizations may choose other HR functions such as succession planning, HR risk management or talent management based on their context.

After choosing suitable criteria and their related sub-criteria, in the second step, these criteria should be weighted. In other words, experts should determine the relative importance of these criteria in the process of assessing municipal districts. The results of this step in our numerical example showed that the employee attitudes followed by work-related knowledge and HR activities weight more than other criteria.

Finally, in the last step, municipal districts should be ranked according to the weighted HC criteria. In this study a fuzzy multiple criteria decision making (MCDM) method means fuzzy TOPSIS was applied in order to rank the alternatives. The results of numerical example showed that the third municipal district has the highest HC capability in comparison with two other districts.

CONCLUSION

Generally, Due to the importance of human capital, evaluating the performance of HC could help the managers to be aware of the organization's status from the human capital management standpoint ([Tavakoli et al., 2017](#)).

Following the above introduced process, the municipality organization could use the best municipal district as the benchmark and determine improvement actions for the other districts according to their shortcomings. For example if the benchmark municipal district has the best HR activities, these functional activities could be used as the standard in other districts. It is worth saying that this framework could be applied in other industries or organizations as a basis for evaluating the HC capability of different branches, departments and the like.

In addition, other MCDM techniques such as ANP could be applied in order to weight the criteria or rank

the alternatives. Integrating these techniques with fuzzy approach could help the practitioners avoiding subjective judgments. Recently, some researchers such as [Wudhikarn \(2018\)](#) pay attention to the probable cause and effects of intellectual capital dimensions. Therefore, it is also suggested that the inter-relationship among human capital criteria be considered in future studies.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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