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A MODIFIED ANALYTIC HIERARCHY APPROACH IN RANKING HUMAN-CAPITAL INDICATORS

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Abstract: Evaluation on human-capital development and a knowledge-based economy becomes increasingly important as several approaches have been proposed. One of the popular methods in multi-criteria evaluation is the pair-wise comparison of Analytic Hierarchy Process (AHP). However, single evaluation in pair-wise comparison of AHP seems not very comprehensive in handling of human judgement. Therefore, this study aims to propose a modified analytical-hierarchy process by considering two-sided conflicting judgement and test the proposed approach to ranking indicators of human capital in Malaysian organisations. The theory of Conflicting Bifuzzy Sets (CBFS) was hybridised into AHP to form a modified version of decision-making tool that employed linguistic judgement and pair-wise comparison. The modified approach was employed to integrate the multi-facets preferences of five criteria of human capital in establishing the importance of the four identified indicators. A case study of human-capital measurement is presented and the proposed model is applied to facilitate the decision-making process. Interviews with three decision-makers were administered to collect linguistic data over the comparative judgement of human-capital measures in Malaysia. The results show that succession rate of training programmes is the most important measurement indicator and creating result by using knowledge is the least-important measurement indicator. The overall ranking reflects the importance of measurement indicators in steering Malaysia to become a worthy human-capital investment.

KEYWORDS: Analytic Hierarchy Process, Conflicting Bifuzzy Set, Ranking, Human capital, Decision-making, Hierarchical layer

Introduction

In the history of development economics, human capital (HC) has been thought of as a key factor in developing human potential. The formal concept of HC was developed in the 1960 by a group of economists associated with the University of Chicago (Becker, 1964). Nearly twenty years later, Becker, (1993) defined HC as expenditures on education, training, medical care to produce human capital. Husz, (1988) forwarded a definition of HC as a function of time, experience, knowledge and abilities of an individual household or a generation, which can be used in the production process. Other authors, for example Schultz ,(1981) defined human-capital investment as enrolment rates multiplied by the cost of education for one individual. Lucas, (1988) measured human capital probably by expenditures on education and external human capital, which he believed to be able to measure by calculating the returns to land. It seems that there are no perfect and comprehensive definitions of HC despite its important contribution in human development in an enterprise. The essence of HC is the sheer intelligence of the organisational member. Perhaps it could appropriate to suggest that HC as the aggregation of investments in areas that accounted in lives such as education, health, on-the-job training. Thus, it is not incorrect to say that investment in HC may yield benefit to economy, thereby indirectly associated with sustainable development. It seems perfectly true to say that HC represents the individual knowledge stock of an organisation as represented by its employees. Implicit knowledge indeed is an asset of the employees in an organisation and constitutes

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one of the most crucial elements that affect the work performance. Thus, HC can be represented by intangible assets embodied by individuals that inhabit an organisation and need to be managed wisely. However, the existence of implicit knowledge is not sufficient for the performance of the organisation until the knowledge translates explicitly to the employee. One of the possible ways to customise the knowledge is through measurements and evaluations.

The fact is known that one of the key factors in human management is evaluation and measurement. One should not ignore the importance of evaluation in HC management. No one in the work study field would deny that evaluation is an important part of the management process. Indeed, evaluation is vital for sustaining successes of an organisation. Evaluation is a common activity in management flowcharts and, in fact, it is the fundamental basics of any management system. Dagum & Slottje, (2000) made a breakthrough contribution to HC evaluation. They combined its microeconomic estimation as a standardised latent variable with the macroeconomic estimation of its average value in the population. The standardised latent variable is obtained by applying the partial least-squares method after transforming the qualitative indicators considered as investments in human capital and called formative indicators. Average of variables and partial least-squares methods are among the common analyses in statistical approach. The method, however, received an improvement by Vittadini & Lovagtio, (2007). The latter introduced an improved statistical method of household HC estimation as standardised latent variable. Nevertheless, measurement and evaluation is something intangible and linked with human judgement, therefore other approaches in decision-making were proposed. TOPSIS, outranking and analytic hierarchy process (AHP) are three of the most frequently used multiple-criteria decision-making (MCDM) techniques. Based on existing literature, AHP has been widely used as a useful MCDM tool or as a weight-estimation technique in many areas such as selection, evaluation, planning and development, decision-making, forecasting, and so on (Vaidya & Kumar, 2006). Pair-wise comparisons are made of the elements of each hierarchy by means of a nominal scale. Then, comparisons are quantified to establish a comparison matrix, after which the eigenvector of the matrix is derived, signifying the comparative weights among various elements of a certain hierarchy. Finally, the eigenvalue is used to assess the strength of the consistency ratio of the comparative matrix and determine whether to accept the information.

The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Another important advantage of the AHP is that it allows for inconsistency in judgement and measures the degree to which the judgements are inconsistent and establishes an acceptable tolerance level for the degree of inconsistency. An extensive description of AHP in addressing comparisons and multi-attribute utility theory can be found in Dyer (1990a), Harker & Vargas (1990), and Saaty (1988). Users of the AHP first decompose their decision problem into a hierarchy of more easily-comprehended sub-problems, each of which can be analysed independently. The elements of the hierarchy can relate to any aspect of the decision problem, tangible or intangible, carefully-measured or roughly-estimated, well- or poorly-understood, anything at all that applies to the decision at hand. Once the hierarchy is built, decision-makers systematically evaluate its various elements, comparing them to one another in pairs. In making the comparisons, decision-makers can use concrete data about the elements, or they can use their judgements about the elements' relative meaning and importance. In short, AHP is a multi-criteria decision method that utilises structured pair-wise comparisons among systems of similar alternative strategies to produce a scale of preference.

The AHP has been used in fields such as government, business, industry and healthcare. Chow and Luk (2005) used AHP framework to measure service quality in fast-food restaurant industry. The AHP procedure provides a ranking order of firms with respect to the dimensions that define service quality. In a business-related research, Kim and Hwang (2005) applied AHP to the evaluation of customer-oriented success factors in mobile commerce. The study aimed to explain the factors that affect success in mobile commerce, and then evaluate and rate these factors by analysing components of commercial activity in the mobile Internet environment using the AHP. Recently, Sambasivan and Fei (2008) used the AHP to find the relative weights and priorities of critical success factors and benefits among Malaysian companies in the electrical and electronics sector. The results were presented in the order of importance of critical success factors. The technique also extended to health-care analysis and several studies have applied the AHP for the evaluation of health-care facilities and in health-care policy analysis. For example, Liberatore and Nydick (2008) reviews extensively the application of AHP in medical and health-care decision-making. In health sciences, Abdullah *et al*., (2009) and Abdullah and Azman (2011) applied AHP in ranking of factors associated with cancer risk and determinant of obesity. The AHP has found its widest application in multi-criteria decision-making in planning and resource allocation and in many other fields (Byun, 2001; Ngai, 2003; Sarkis & Talurri, 2004). Obviously AHP has been successfully applied in most fields of studies and can equally be extended to managing HC.

It is noted that most of the evaluation in MCDM is made in 'conflicting' nature. For example, if ones say that customer service at a hotel is highly satisfactory, then this does not reflect that they are fully satisfied with the service. Perhaps deep inside their heart, there are some degrees of dissatisfaction. These conflicts are compromised through a mathematical theory which is called conflicting bifuzzy sets (CBFS). Details of the conflicting judgements and their computation procedures can be retrieved from Zamali *et al.* (2008), and Imran *et al.* (2008). Based on the highly-regarded pair-wise comparison method of AHP and the new idea of CBFS, this paper aims to fulfil the two objectives. To handle the conflicting judgements, this paper proposes a modified version of the pair-wise comparison of AHP. The second objective is to test the proposed method in a case study of human-capital indicators evaluation. Rather than use typical statistical methods in the case study, the approach advocated here uses a modified Analytic Hierarchy Process (AHP) approach which empower the process of pair-wise comparisons in determining the relative importance or priority of human-capital indicators.

Preliminaries

In this section, the basic fuzzy sets and intuitionistic fuzzy-sets definition were briefly reviewed. The bifuzzy concepts were then thoroughly discussed with emphasis on how the proposed idea were derived for evaluation purposes.

Definition 1. A fuzzy set A in a universe of discourse $\boldsymbol{X}$ is characterised by a membership function $\mu_A(x)$ which associates with each element x in $\boldsymbol{X}$ a real number in the interval [0,1]. The function value $\mu_A(x)$ is termed the grade of membership of x in (Zadeh, 1965).

Atanassov (1986; 1999) extended Zadeh's idea twenty years later by using the concepts of dual-membership degrees in each of the set's discourse by giving both a degree of membership and a degree of non-membership which are more-or-less independent from one other with the sum of these two grades being not greater than 1. The theory is named Intuitionistic Fuzzy Sets (IFS) and is given as the following definition:

Definition 2. Let a set A be fixed. An intuitionistic fuzzy set or IFS A of $\boldsymbol{X}$ is an object having the form:

$$A = \{\langle x, \mu_A(x), \gamma_A(x)\rangle \mid x \in \boldsymbol{X}, 0 < \mu_A(x) + \gamma_A(x) \leq 1\}$$

where the function $\mu_A(x) : \boldsymbol{X} \rightarrow [0,1]$ and $\gamma_A(x) : \boldsymbol{X} \rightarrow [0,1]$ define, respectively, the degree of membership and degree of non-membership of the element $x \in \boldsymbol{X}$ to the set A. IFS approaches involve setting or fixing the limitation of membership degree and non-memberships degree for any events in the range of [0, 1] (Atanassov, 1986; 1999).

However, in real phenomena these limited conditions are clearly not always true and the idea of solutions is needed beyond these boundaries. For example, if the performance of a candidate is said to be '*good*' ($\mu_A = 0.7$), it does not mean that the '*poor*' performance was always, $\gamma_A(x) = 1 - 0.7 = 0.3$, but it can be more than 0.3 (for example, 0.35). Hence, it is natural not to see that $0 < \mu_A(x) + \gamma_A(x) \leq 1$, where $\mu_A(x)$ and $\gamma_A(x)$ cannot both occur at the value 0 or 1 at *X*. For example, two fuzzy set '*good*' and '*bad*' are usually observed for the performance of a candidate. The fuzzy set '*bad*' need not be the complement of the fuzzy set '*good*'. If the '*good*' performance with $\mu_A(x) = 0.7$, the value for '*bad*' performance need not be 0.3, but could be $\gamma_A(x) = 0.4$ and $\mu_A(x) + \gamma_A(x) = 0.7 + 0.4 > 1$. Thus, the limitation of the bound by considering two conflicting bifuzzy set $\mu : X \rightarrow [0,1]$ and $\gamma : X \rightarrow [0,1]$ prompts the two conflicting sets to be defined on the same premise of *X*.

If $\mu : \boldsymbol{X} \rightarrow \boldsymbol{I}$ and $\gamma : \boldsymbol{X} \rightarrow \boldsymbol{I}$ are two fuzzy sets, bifuzzy set can be defined as $(\mu,\gamma): \boldsymbol{X} \text{ x } \boldsymbol{X} \rightarrow \boldsymbol{I}$ as in the following structure shown in Figure 1.

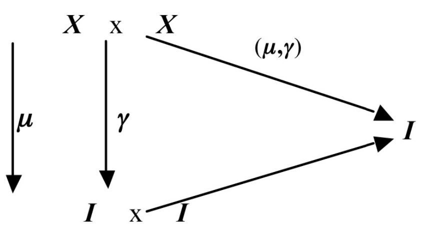

Figure 1: The bifuzzy set structure.

Hence, it can be seen that $0 \leq \mu(x) + \gamma(x) \leq 2$, where $0 \leq \mu(x) \leq 1$ and $0 \leq \gamma(x) \leq 1$. Since the value of fuzzy set are in [0,1], 0.5 is defined as the threshold value when the value is greater than 0.5 is said to be dominant. If the value is less than 0.5, it is then said to be under-dominant.

Now, if there are two fuzzy sets which are conflicting on the same $\boldsymbol{X}$, it can be seen that the values of $\mu(x)$ and $\gamma(x)$ cannot be both dominant and/or both under-dominant, concurrently. Hence, for two conflicting bifuzzy sets (CBFS) μ and γ on the same $\boldsymbol{X}$, if μ is dominant, then γ must be under dominant and it is true conversely. For example, the two fuzzy sets "*good*" and "*bad*" are observed for performance of a candidate. The fuzzy set "*bad*" need not necessarily be the complement of the fuzzy set "*good*". If the "*good*" performance with $\mu_z(x) = 0.7$, the value for "*bad*" performance need not be 0.3, but may be $\gamma(x) = 0.4$ and $\mu(x) + \gamma(x) = 0.7 + 0.4 > 1$. Thus, the conflicting bifuzzy sets can be defined (μ,γ) as $\boldsymbol{X} \text{ x } \boldsymbol{X} \rightarrow \boldsymbol{I}$ such that $0 < \mu(x) + \gamma(x) < 1.5$. Thus, two conflicting bifuzzy sets $\mu : \boldsymbol{X} \rightarrow [0,1]$ and $\gamma : \boldsymbol{X} \rightarrow [0,1]$ can be considered defined on the same premises of $\boldsymbol{X}$ to be given as the following definition.

Definition 3 Let a set $\boldsymbol{X}$ be fixed. A *conflicting bifuzzy set A* of $\boldsymbol{X}$ x $\boldsymbol{X}$ is an object having the following form:

$$A = \{\langle x, \mu_A(x), \gamma_A(x)\rangle \mid x \in \boldsymbol{X};\ 0 < \mu_A(x) + \gamma_A(x) \leq 1.5\}$$

where the functions $\mu_A : \boldsymbol{X} \rightarrow [0,1]$ represent the *positive degree* of *x* with respect to *A* and $x \in \boldsymbol{X}$ such that $\mu_A(x) \in [0,1]$, and the functions $\gamma_A : \boldsymbol{X} \rightarrow [0,1]$ represent the *negative degree* of *x* with respect to *A* and $x \in \boldsymbol{X}$ such that $\gamma_A(x) \in [0,1]$, and the $0 < \mu_A(x) + \gamma_A(x) \leq 1.5$ (Zamali, 2009).

The strength of the above definitions becomes the platforms to characterise the modified version of AHP.

A Modified Analytical Hierarchy Process

Saaty (1977, 1980) developed AHP with the aim to help decision-makers in evaluating multiple attributes or alternatives. The method allows a decision-maker to structure complex problems in the form of a hierarchy (Benyoucef & Canbolat, 2007). A hierarchy commonly contains at least three levels such as the goal, the criteria for meeting the goal and the alternatives. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements for relating those elements to overall goals and evaluating alternative solution. The five basic steps of AHP are organised as follows:

Step 1: Construct the hierarchical structure

Criteria are compared with respect to the goal. A *n* x *n* matrix, denoted as *A*, is created using the pair-wise comparisons with the elements a_{ij} indicating the value of i^{th} criterion relative to j^{th} criterion as shown in the following formula.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}_{n \times n} \quad (7)$$

The values a_{ij} are obtained by the a_{ij}=1 =1/a_{ij}, where $a_{ij} > 0$, for all *i*. Therefore, if a number is assigned to element *i* when compared to element *j*, then *j* has the reciprocal value when compared with *i*.

Step 2: Find the eigenvector by normalising the pair-wise comparisons

Once construction of the matrix of comparison is done, the next step is to determine the weights of the criteria, in which w_i is the i^{th} criterion for criteria. In order to determine w_i, and make w_i consistent, its entries are normalised by dividing them by their sum. This is repeated for all columns to obtain the normalised matrix $A(A_{norm})$ as follows.

$$A_{norm} = \begin{bmatrix} a_{11}/a'_1 & a_{12}/a'_2 & a_{13}/a'_3 & \cdots & a_{1n}/a'_n \\ a_{21}/a'_1 & a_{22}/a'_2 & a_{23}/a'_3 & \cdots & a_{2n}/a'_n \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{n1}/a'_1 & a_{n2}/a'_2 & a_{n3}/a'_3 & \cdots & a_{nn}/a'_n \end{bmatrix}_{n \times n}$$

a_{ij} in the above matrix is defined as the pair-wise comparisons of i^{th} row relative to i^{th} column, and a_{ni} is the sum of the pair-wise comparisons in the i^{th} column.

Step 3: To compare the alternatives pair-wise with respect to each criterion.

Since there are *n* criteria in a decision-making problem, there will be *n* matrices of judgements for the alternatives. Each matrix contains the weights for each alternative and is determined in the fashion as described above for determining the weights for criteria.

Step 4: Hierarchical layer sequencing

Select the most preferred alternative among *m* alternatives. If there are *n* criteria and *m* alternatives, then a matrix $A_{AHP\text{-}Score}$ of size *n* x *m* is created. The $A_{AHP\text{-}Score}$ matrix contains the weight results a_{ij} for the alternative with respect to the criteria. According to the AHP, the best alternative (in the maximisation) is indicated by the following relationship.

$$A_{AHP\text{-}Score} = max \sum_{j=1}^{n} a_{ij}\, w_j \text{ , } for\ i = 1,2,3,...,m.$$

where:

$A_{AHP\text{-}Score}$ = Overall relative rating

a_{ij} = Average normalisation rating for *j* with respect to factor *i*.

w_j = Average normalisation weight for *i*.

Step 5: Ranking the alternatives.

Obviously, ranking is generated according to magnitude of weights. The highest ranking or the best alternative is chosen based on the highest weight.

Based on the theory of CBFS, this paper proposes some modifications to AHP, specifically in Step 1 and Step 2, without missing the novelty of AHP.

Modifications in Step 1

i) In this step, the determination of hierarchical structure evaluation is made by utilising both positive and negative components in conflicting judgement but still maintaining the accustomed procedures.

ii) A *n* x *n* matrix, denoted as *A,* is created using the pair-wise comparisons with the elements a_{ij} indicating the value of i^{th} criterion relative to j^{th} criterion as shown in the following formula.

$$\begin{bmatrix} 1 & (a^+_{12}, a^-_{12}) & \cdots & (a^+_{1n}, a^-_{1n}) \\ (a^+_{21}, a^-_{21}) & 1 & \cdots & (a^+_{2n1}, a^-_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ (a^+_{n1}, a^-_{n1}) & (a^+_{n2}, a^-_{n2}) \cdots & & 1 \end{bmatrix}$$

The values a_{ij} are obtained by the a_{ii} = 1,(a^+_{ij} = 1/ a^+_{ji} , a^-_{ij} = 1 – a^-_{ji}), where $a_{ij} > 0$ for all *i*. Therefore, if a number is assigned to element *i* when compared to element *j*, then *j* has the reciprocal value when compared with *i*.

Modifications in Step 2

Arithmetic mean is the most commonly-used combination operator in finding consensus or agreeable value but this sometimes fails to discriminate between evaluation values. In this paper, the geometric mean is suggested as a combination operator for evaluating the positive and 'non-negative' values in judgement. This paper suggests the geometric mean for agreeable value in judgements.

$$M_G(\mu,v) = \sqrt{\mu(1-v)}$$

The rest of the AHP procedure remains unchanged. Based on the modified version of AHP, a case study in human-capital indicators evaluation is applied. For simplicity, the modified version is assigned as CBFS-AHP and will be used throughout this paper.

A Case Study: Human Capital Indicators

Prioritisation of human-capital indicators banks on the strengths of the CBFS-AHP theory as a decision-making tool.

Hierarchical Structure

In order to examine the feasibility of the proposed method, a case study of HC prioritisation was applied. According to Becker *et al.,* (2001), there are five main criteria to maximise HC in an organisation. These criteria are Talent (T), Strategically Integration (SI), Cultural Relevance (CR), Knowledge Management (KM) and Leadership (L). There are fourteen sub-criteria listed under the five criteria. Four sub-criteria under T are Growing Talent Pool (GTP), High Potential Development (HPD), Select, Assimilate and Retain Key Talent (SAR) and Reduce Turnover (RTO). Three sub-criteria under SI are Organisational Strategy (OS), Industry Trends (IT) and Integrated Human Capital Technology Infrastructure (ITI). Two sub-criteria under CR are Relationship Building (RB) and Coordination of HC systems build organisational Mind Set (SM). Another three sub-criteria under KM are Knowledge Creation (KC), Knowledge Transfer (KT) and Knowledge Utilization (KU). The last two sub-criteria that fall under L are Organisational Leadership (OL) and Social Responsibility (SR).

In Becker *et al.,* (2001), 53 human-resource efficiency indicators are defined. In another research, Abeysekera and Guthrie (2004) define HC with 25 indicators. Bontis et al., (2000) listed 20 indicators for HC. So many indicators sometimes make things complicated and redundant due to overlapping in meanings and interpretations. Perhaps it is better to group sub-indicators into a number of main indicators. The present research summarised indicators in Bontis *et al.,* (2000) into four main indicators. The four main indicators are Creating Results by Using Knowledge (CRbUK), Employee' Skill Index (ESI), Sharing and Reporting Knowledge (SaRK), and Succession Rate of Training Programme (SRoTP). This research focuses on prioritising the four main indicators of HC which is called the alternatives in the CBFS-AHP decision model based on the five criteria. The hierarchical structure of evaluation model, alternatives and criteria can be seen in Figure 2.

Linguistic Judgement

In accordance with the purpose and framework of the research, a group of three experts' opinions were sought via interviews to elicit information on the preference of the selected criteria and alternatives. Two academicians from two public universities in Malaysia and one high-ranking officer at the Public Service Department of the Malaysian Government were the experts believed to be the right personnel to offer linguistic data in the evaluation. All the three experts are considered as the decision-makers in the multi-criteria decision-making problems. The decision-makers were asked to compare pairs of indicators (for example CRbUK versus USI) and to indicate whether they felt that one indicator was 'equally important' or 'extremely important' to another indicator. Pair-wise comparison is used for both positive and non-negative evaluations. In this section, fuzzy analytic hierarchy process scales ranging [0, 1] proposed by Zamali, *et al.,* (2010) are used instead of Saaty scale 1 – 9. The proposed scale is given in Table 1.

Another level of comparison was made to compare the relative importance of criteria towards indicators. The experts were asked to

Figure 2: Hierarchical Structure of Model in Application.

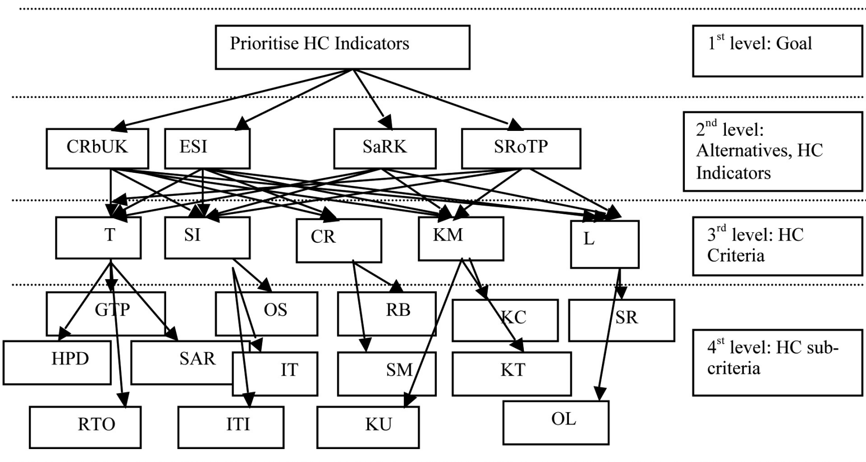

Table 1: The definition of entries values for pair-wise comparison.

Scale (a_{ij})	*Definition*
0.0	No comparison can be made
0.1	Objective *i* is "not important" compared to *j* objective
0.3	Objective *i* is "least important" compared to *j* objective
0.5	Objective *i* is "equal important" compared to *j* objective
0.7	Objective *i* is "more important" compared to *j* objective
0.9	Objective *i* is "very important" compared to *j* objective
0.2, 0.4, 0.4, 0.8	The importance values in between of above odd numbers

state their preferences on a nine-point scale of relative importance. The scales are similar to the ones used in the original instrument (Saaty, 1980). According to the scale used in this study, 1 represented 'equally important', 2 represented 'equally important to somewhat important', 3 represented 'somewhat more important', 4 represented 'somewhat important to moderately important', 5 represented 'moderately important', 6 represented 'moderately important to very important', 7 represented 'very important', 8 represented 'very important to extremely important' and 9 represented 'extremely important'.

The evaluation assigns A = {CRbUK, ESI, SaRK, SRoTP} as the alternatives, C= {T, SI, CR, KM, L} as the criteria and $W=\{w_1,w_2,w_3,w_4\}$ as the *4 x 1* matrix, where w_{ij} is the relative importance weight of the five criteria. The proposed five steps methods of CBFS-AHP are applied to find prioritisation of human-capital measurement indicators.

Step 1: Construct the hierarchical structure

Based on the experts' opinions, the pair-wise comparison matrix for each alternative based on both positive and negative component for criteria is given as follows:

C =

	T	SI	CR	KM	L
T	(1,1)	(0.75,0.80)	(0.75,0.70)	(0.75,0.75)	(0.7,0.8)
SI	(1.33,1.25)	(1,1)	(0.75,0.7)	(0.75,0.75)	(0.7,0.8)
CR	(1.33,1.43)	(1.31,1.43)	(1,1)	(0.7,0.75)	(0.7,0.8)
KM	(1.33,1.33)	(1.33,1.33)	(1.43,1.33)	(1,1)	(0.7,0.75)
L	(1.43,1.25)	(1.43,1.25)	(1.43,1.25)	(1.43,1.33)	(1,1)

Step 2: Find the eigenvector by normalizing the pair-wise comparisons

C =

	T	SI	CR	KM	L
T	(0.16,0.16)	(0.13,0.14)	(0.14,0.14)	(0.16,0.16)	(0.18,0.19)
SI	(0.21,0.20)	(0.17,0.17)	(0.14,0.14)	(0.16,0.16)	(0.18,0.19)
CR	(0.21,0.23)	(0.23,0.25)	(0.19,0.20)	(0.15,0.16)	(0.18,0.19)
KM	(0.21,0.21)	(0.23,0.23)	(0.27,0.27)	(0.22,0.22)	(0.18,0.18)
L	(0.22,0.20)	(0.24,0.22)	(0.27,0.25)	(0.31,0.29)	(0.26,0.24)

Using the geometric mean, the matrix below is obtained

C_1 =

	T	SI	CR	KM	L
T	0.3615	0.3326	0.3469	0.3681	0.3856
SI	0.4074	0.3764	0.3469	0.3681	0.3856
CR	0.4001	0.4148	0.3863	0.3557	0.3856
KM	0.4040	0.4193	0.4419	0.4111	0.3885
L	0.4217	0.4380	0.4470	0.4679	0.4469

then , $\{w_{11}, w_{21}, w_{31}, w_{41}, w_{51}\} = \{0.1811, 0.1902, 0.1961, 0.2084, 0.2241\}$

Step 3: To compare the alternatives pair-wise with respect to each criterion.

The pair-wise comparison matrices for each alternative based on both positive and negative component for the criteria respect to the alternatives are given as follows:

i) Criterion T

$$T = \begin{array}{c} \\ CRbUK \\ ESI \\ SaRK \\ SRoTP \end{array} \begin{array}{c} \begin{array}{cccc} CRbUK & ESI & SaRK & SRoTP \end{array} \\ \begin{pmatrix} 0.4014 & 0.3637 & 0.4041 & 0.4279 \\ 0.4545 & 0.4170 & 0.3811 & 0.4236 \\ 0.4305 & 0.4465 & 0.4327 & 0.4092 \\ 0.4391 & 0.4577 & 0.4853 & 0.4635 \end{pmatrix} \end{array}$$

$\{a_{11}, a_{21}, a_{31}, a_{41}\} = \{0.2336, 0.2452, 0.2514, 0.2699\}$

ii) Criterion SI

$$SI = \begin{array}{c} \\ CRbUK \\ ESI \\ SaRK \\ SRoTP \end{array} \begin{array}{c} \begin{array}{cccc} CRbUK & ESI & SaRK & SRoTP \end{array} \\ \begin{pmatrix} 0.4114 & 0.3785 & 0.4019 & 0.4236 \\ 0.4114 & 0.4088 & 0.3852 & 0.4134 \\ 0.4472 & 0.4649 & 0.4410 & 0.4236 \\ 0.4536 & 0.4578 & 0.4777 & 0.4635 \end{pmatrix} \end{array}$$

$\{a_{11}, a_{21}, a_{31}, a_{41}\} = \{0.2354, 0.2358, 0.2589, 0.2699\}$

iii) Criterion CR

$$CR = \begin{array}{c} \\ CRbUK \\ ESI \\ SaRK \\ SRoTP \end{array} \begin{array}{c} \begin{array}{cccc} CRbUK & ESI & SaRK & SRoTP \end{array} \\ \begin{pmatrix} 0.4087 & 0.3916 & 0.4015 & 0.4255 \\ 0.4329 & 0.4196 & 0.3920 & 0.4308 \\ 0.4384 & 0.4527 & 0.4300 & 0.4070 \\ 0.4471 & 0.4514 & 0.4822 & 0.4615 \end{pmatrix} \end{array}$$

$\{a_{11}, a_{21}, a_{31}, a_{41}\} = \{0.2368, 0.2437, 0.2514, 0.2681\}$

iv) Criterion KM

$$KM = \begin{array}{c} \\ CRbUK \\ ESI \\ SaRK \\ SRoTP \end{array} \begin{array}{c} \begin{array}{cccc} CRbUK & ESI & SaRK & SRoTP \end{array} \\ \begin{pmatrix} 0.4068 & 0.3771 & 0.4121 & 0.4266 \\ 0.4498 & 0.4210 & 0.4022 & 0.4173 \\ 0.4355 & 0.4564 & 0.4419 & 0.4310 \\ 0.4355 & 0.4564 & 0.4558 & 0.4514 \end{pmatrix} \end{array}$$

$\{a_{11}, a_{21}, a_{31}, a_{41}\} = \{0.2360, 0.2458, 0.2566, 0.2616\}$

v) Criterion L

$$L = \begin{array}{c} \\ CRbUK \\ ESI \\ SaRK \\ SRoTP \end{array} \begin{array}{c} \begin{array}{cccc} CRbUK & ESI & SaRK & SRoTP \end{array} \\ \begin{pmatrix} 0.3459 & 0.3660 & 0.3709 & 0.4237 \\ 0.5042 & 0.3876 & 0.3635 & 0.4237 \\ 0.5208 & 0.5596 & 0.3955 & 0.4193 \\ 0.3342 & 0.4011 & 0.5937 & 0.4583 \end{pmatrix} \end{array}$$

$\{a_{11}, a_{21}, a_{31}, a_{41}\} = \{0.2193, 0.2445, 0.2759, 0.2602\}$

Step 4: Hierarchical layer sequencing

CBFS-AHP score for each indicator is computed prior to selecting the most preferred alternative among the four.

$$\begin{aligned} CrbUK &= 0.2336(0.1811) + 0.1902(0.2354) + \\ &\quad 0.1961(0.2368) + 0.2084(0.2360) + \\ &\quad 0.2242(0.2193) \\ &= 0.2301, \end{aligned}$$

Similarly,

$ESI = 0.2452(0.1811) + ... + 0.2445(0.2242) = 0.2431$

$SaRK = 0.2514(0.1811) + ... + 0.2759(0.2242) = 0.2594$

$SRoTP = 0.2699(0.1811) + ... + 0.2602(0.2242) = 0.2656$

These scores represent the magnitude for human-capital indicators.

Step 5: Ranking the alternatives.

Finally the scores are ranked or prioritised according to their magnitudes. Based on the result in Step 4, the indicators' ranking is given in Table 2.

Table 2: Ranking of Human-Capital Indicators.

Alternative	Total Score	Ranking
CRbUK	0.2301	4
ESI	0.2431	3
SaRK	0.2594	2
SRoTP	0.2656	1

The evaluation comes to conclude that the best alternative is succession rate of training programmes (SRoTP), followed by sharing and reporting knowledge (SaRK). The indicator of employee skill index (ESI) ranked at third place and the last alternative in the ranking is creating result by using knowledge (CRbUK).

Conclusion

The present millennium sees the importance of knowledge in managing an organisation. Managers now realise that the value of their organisation not only depends on tangible assets but knowledge assets are equally important. Knowledge growths are not beneficial unless they can relate to human beings. Knowledge and human are two well-connected words to coin the term human capital. However, human-capital literature suggests that multi indicators constitute human capital, thereby perpetuating various approaches in evaluation.

The paper presents a new approach for evaluating the pair-wise comparison and the performance score of human-capital indicators using the approach based on the incorporation of analytic hierarchy process dual human judgement. Human judgement naturally reckons positive and negative sides to offer a comprehensive evaluation process. This paper proposes a two-sided evaluation with an extended membership constraint in Conflicting Bifuzzy Sets-Analytic Hierarchy Process and tests the new approach for evaluating the pair-wise comparison in Human-Capital indicators evaluation. Based on the proposed new idea, it is found that the consideration for both positive and negative aspects in evaluation process yielded the final decision perspective where the indicator of succession rate of training programmes was ranked as the most preferred indicator in Malaysian organisational management context. The new method seems feasible and possibly could be extended to any decision-making environment. Further research, perhaps other fuzzy multi-criteria evaluation methods such as TOPSIS or fuzzy outranking methods can be tested. A comparison with other decision-making methods is still open as one of the mechanisms for method validation and robustness.

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