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Intuitionistic Fuzzy Analytic Hierarchy Process Approach in Ranking of Human Capital Indicators

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Abstract: Evaluation on Human Capital (HC) 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). This study aims to rank human capital indicators using a hybridization of the AHP and two-sided evaluation in Intuitionistic Fuzzy Sets (IFS). The new Intuitionistic Fuzzy Analytic Hierarchy Process (IFAHP) is used to evaluate the four main indicators of HC. The IFAHP approach measures indicators of HC by considering positive attributes and negative attributes of HC indicators concurrently via expert judgments. A fourteen items questionnaire was employed to elicit linguistic data from three experts in the field of HC management. Linguistic judgments of the indicators in pair-wise comparison evaluation are computed using the five step algorithm of the IFAHP approach. The results show that the creating result by using knowledge is the highest in the ranking. Of the four indicators, Employee's Skill Index is the lowest in the ranking. The ranking surely reflects the importance of the indicators in managing HC especially in Malaysian enterprises.

Key words: Analytic hierarchy process, intuitionistic fuzzy set, ranking, human capital, indicators

INTRODUCTION

In recent years, there has been an increasing interest to proliferate the idea of Human Capital (HC) in organization's administration or enterprise. HC is thought to be no less important with other components in managing organization as it believes to be a source of innovation, creativity and strategic renewal. In highly publicized books, Naisbitt and Aburdene (1985) and Naisbitt (1982) speak out the importance of HC. They advocate that the knowledge growths are not beneficial unless related to human beings. In any knowledge society, it is not only technologies could be taken into account but HC development is also equally important. Indeed it is very true to place HC as the most important assets in organization since it is the source of creativity in organization. The formal concept of HC was developed in the 1960 by a group of economist associated with the University of Chicago. Becker (1964) led the definition of HC as the aggregation of investments in such areas as education, health, on the job training and migration that enhance an individual's productivity in the labour market and also in non-market activities. As the concept of HC develops, most of the recent literatures limit the scope of HC to the knowledge node. Baptise (2001) refered HC as the knowledge that are developed and valued primarily for the economically productive potential. Husz (1998) forwards a definition of HC as 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) only define HC investment as enrolment rates multiplied by the cost of education for one individual. Lucas (1998) measures HC probably by expenditures on education and external HC, which he believes 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 organizational member. Perhaps, it could appropriate to suggest that HC as the aggregation of investments in areas that accounted in lives such as education, health and on the job training. The scope of HC is pretty vast but it is just right to limit HC to the knowledge node. In this context, it is perfectly true to say that HC represents the individual knowledge stock of an organization as represented by its employees. Implicit knowledge indeed is an asset of the employees in organization and constitutes one of the most crucial elements that affect the work performance. Thus HC can be represented by intangible assets embodied by

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individuals that inhabit the organisation and need to manage wisely. However, the existence of implicit knowledge is not sufficient for performance of the organization until the knowledge translates explicitly to the employee. One of the possible ways to customize the knowledge is through measurements and evaluations. It seems that knowledge is the heart of HC and also can be represented by intangible assets embodied by individuals. However, this asset needs to be evaluated in ensuring sustainable contribution of HC to organization. Evaluation is parts of organization activities with the aim to meeting the goals laid down for them.

Since evaluation is something intangible and normally linked with human judgment, thus many evaluation model based on linguistic judgments were proposed. Top of preference ideal solution, outranking and Analytic Hierarchy Process (AHP) are the three of most frequently methods of evaluation particularly in Multiple Criteria Decision Making (MCDM). Of the three evaluation methods, AHP which was developed by Saaty (1988) has been widely used as a useful MCDM tool or a weight estimation technique. The strength of AHP lies at the pair-wise comparisons of criteria and alternative for each hierarchy by means of a nominal scale. In order to handle uncertain data and incomplete information, the concept of AHP was extended to fuzzy AHP. Development of fuzzy AHP methods and applications have been carried out by many researchers (Boender *et al.*, 1989; Chang, 1996; Cheng, 1996; Barzilai, 1997; Chen, 2000; Hsieh *et al.*, 2004; Gu and Zhu, 2006; Liu and Wang, 2007; Vaidya and Kumar, 2006). It is noted that most of the evaluation in AHP deals with intangible and uncertain concepts. Fuzzy concept was introduced by Zadeh (1965) to describe the relationship between an uncertain quality in form of membership functions. Atanassov (1986, 1999) defined membership function and non membership function through Intuitionistic Fuzzy Set (IFS). Recently, Abdullah *et al.* (2009) have demonstrated the possibility of extending AHP using IFS in proposing a new hybrid decision making method. This new fusion model is denoted as Intuitionistic Fuzzy Analytic Hierarchy Process (IFAHP) and to be used throughout the text. With the new development in decision making model, the present paper opts to apply the IFAHP approach in evaluation of HC indicators. In other word this paper aims to rank the HC indicators in the context of Malaysian organizations.

INTUITIONISTIC FUZZY ANALYTIC HIERARCHY PROCESS

AHP is a ratio scale method used to help decision makers in evaluating multiple attribute alternatives. This method allows a decision maker to structure complex problems in the form of a hierarchy (Benyoucef and 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 (Abdullah *et al.*, 2009). This section presents the five step-wise algorithms for AHP and pair-wise comparison scale in evaluation. Based on the step of AHP, a little contribution is suggested without losing its originality. Specifically, Step 1 and Step 4 are modified to ensure viability of AHP in intuitionistic fuzzy sets environment. Theoretical frameworks and basis for these modifications can be retrieved from Abdullah *et al.* (2009). The algorithm of IFAHP is presented as follows:

Step-wise algorithm for IFAHP: The five steps IFAHP are proposed as follows:

- **Step 1:** Construct the hierarchical structure

First, the criteria are compared with respect to the goal. A n×n matrix, denoted as A is created using the pair-wise comparisons with the elements a_{ij} indicating the value of ith criterion relative to jth criterion, as shown in the following formula:

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

The values a_{ij} are obtained by the $a_{ii} = 1$, $a_{ji} = 1/a_{ij}$, where, $a_{ji}>0$, 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. Determination of hierarchical structure evaluation is executed by utilizing both positive and negative component/aspect of IFS. This modification does not affect the normal procedures and novelty of AHP.

A n×n matrix, denoted as A is created using the pair-wise comparisons with the elements a_{ij} indicating the value of ith criterion relative to jth criterion as shown in the following formula:

$$\begin{pmatrix} (0 \quad 0) & (\mu_{12}^k \quad v_{12}^k) \cdots & (\mu_{1n}^k \quad v_{1n}^k) \\ (\mu_{21}^k \quad v_{21}^k) & (0 \quad 0) \quad \cdots & (\mu_{2n}^k \quad v_{2n}^k) \\ \vdots & \vdots \quad \vdots & \vdots \\ (\mu_{n1}^k \quad v_{n1}^k) & (\mu_{n2}^k \quad v_{n2}^k) \cdots & (0 \quad 0) \end{pmatrix}, \quad k = 1,2,...,K \tag{1}$$

where, $\mu_{ji}^k = v_{ij}^k$ and $v_{ji}^k = \mu_{ij}^k$:

- **Step 2:** Compute the weights priorities for the hierarchy

This step can be divided into two sub-steps.

- Compute the weights priority of each criterion

Based on pair-wise comparison matrix A, the weights of the criteria, in which W_{Ci} is the ith criterion for n criteria are computed using Eq. 2 and 3:

$$A = \begin{bmatrix} a_{11}/b_1 & a_{12}/b_2 & a_{13}/b_3 & \cdots & a_{1n}/b_n \\ a_{21}/b_1 & a_{22}/b_2 & a_{23}/b_3 & \cdots & a_{2n}/b_n \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{n1}/b_1 & a_{n2}/b_2 & a_{n3}/b_3 & \cdots & a_{nn}/b_n \end{bmatrix}_{n\times n} \tag{2}$$

$$W_{ci} = \frac{\sum_{j=1}^{n} (\frac{a_{ij}}{b_j})}{n} \tag{3}$$

where:

$$b_j = \sum_{i=1}^{n} a_{ij}$$

for each j = 1, ..., n.

a_{ij} in the matrix A is defined as the pair-wise comparisons of ith row relative to ith column and b_j is the sum of the pair-wise comparisons in the ith column.

- Compute the weights priorities for the hierarchy of sub-criteria and alternatives with respect to each criterion.

The next procedure is 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 judgments for the alternatives. Each matrix contains the weights W_{SC} for each sub-criterion and alternatives, W_A and can be determined in the same way as described to determining the weights for criteria.

- **Step 3:** Compute the weighted performance, P for each alternatives with respect to each criterion

When the priorities of W_C, W_{SC} and W_A, are obtained, the next is to calculate the weighted performance for each alternative with respect to each criterion. To synthesize the results and obtain the weighted performance of each alternative, the local priorities of a given alternative and sub-criterion with respect to each criterion is multiplied by the priority of the corresponding criterion as follows:

$$P = \begin{bmatrix} W_{C11} \bullet W_{A11} \bullet W_{SC11} \\ W_{C21} \bullet W_{A21} \bullet W_{SC21} \\ \vdots \\ W_{Cij} \bullet W_{Aij} \bullet W_{SCij} \end{bmatrix} \tag{4}$$

- **Step 4:** Compute the composite priority (overall weights in the entire hierarchy)

The resulting products of step 3 are added over all criteria to obtain the composite or global priority for selection the best alternatives. If there are n criteria and m alternatives, then a matrix $A_{AHP\text{-}Score}$ of size n×m is created.

$$A_j = \sum_{i=1}^{n} W_{Cij} W_{Aij} W_{SCij} \text{ for each } j=1,...,n \tag{5}$$

The $A_{AHP\text{-}Score}$ matrix contains the weight result for the alternative, W_A and sub-criteria, W_{SC} with respect to the criteria, W_C.

This paper also improves Step 4 in AHP by introducing geometric mean as combination operator as a move to accommodate with IFS. The most commonly used combination operator is the arithmetic mean but this sometimes does not clearly discriminate between evaluation values. This paper suggests geometric mean as a combination operator for evaluating the 'positive' μ and 'non-negative' v values given as follows:

$$M_G(\mu, v) = \sqrt{\mu(1-v)} \tag{6}$$

- **Step 5:** Ranking the alternatives

According to the AHP, the best alternative (in the maximization) is indicated by the following relationship:

$$A_{AHP\text{-}Score} = \max \{A_j\} \text{ for } j = 1, ..., n \tag{7}$$

where:

$A_{AHP\text{-}Score}$ = Composite priority
W_A = Priority of alternatives with respect to each criterion
W_{SC} = Priority of sub-criteria with respect to each criterion
W_C = Priority for the corresponding criterion

Obviously, for alternative $X_i \in X$ (i = 1, 2, ..., m) is generated according to the decreasing order.

Based on these improvements, a real case study in human capital evaluation is applied using the proposed method.

A HUMAN CAPITAL CASE STUDY

This study applies the proposed IFAHP decision making method in evaluation of human capital indicators.

Hierarchical structure: In order to examine the feasibility of the proposed method, a case study of HC prioritization was applied. According to Becker *et al*. (2001), there are five main criteria to maximize HC in an organization. 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 organizational 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 Organizational Leadership (OL) and Social Responsibility (SR).

Becker *et al*. (2001) defined 53 human resource efficiency indicators. In another research, Abeysekera and Guthrie (2004) defined HC with 25 indicators. Bontis *et al*. (2000) listed 20 indicators for HC. Many indicators may cause a high risk in IFAHP computations and possibly, it is better to group into a number of main indicators. The present research summarised indicators by 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 Program (SRoTP). This research focuses on ranking of the four main indicators of HC which is called as the alternatives in decision model based on the five criteria. The hierarchical structure of evaluation model, alternatives and criteria can be seen in Fig. 1.

Linguistic judgment: 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-rank officer at Public Service Department of Malaysian Government are the experts that believe 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

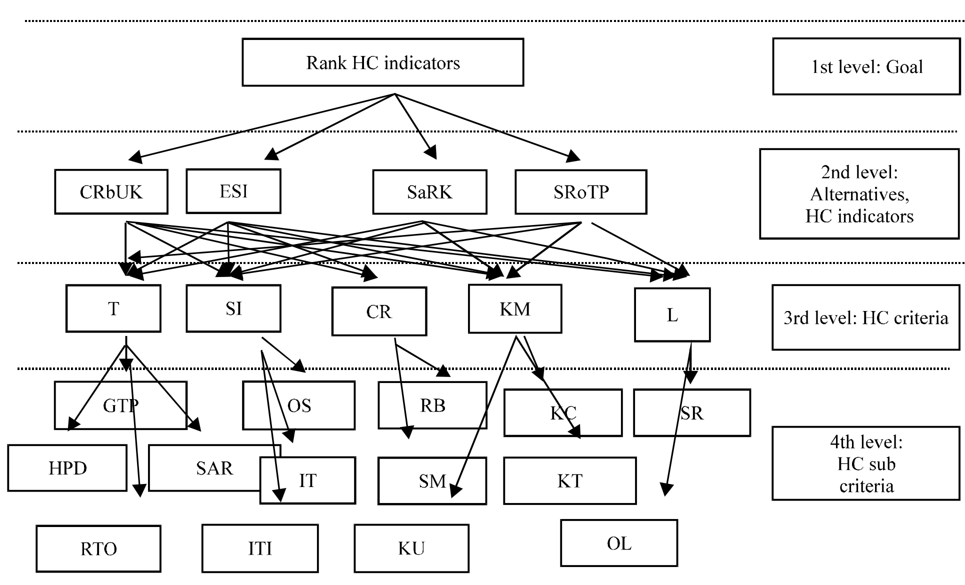

Fig. 1: Hierarchical structure of model in application

Table 1: Definition of entries values for pair-wise comparison

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

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

'equally important' or 'extremely important' to another. Pair-wise comparison is used for both positive and negative evaluations. In this section, fuzzy analytic hierarchy process scales of [0, 1] (Tarmudi *et al*., 2010) were utilised 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 toward indicators. The experts were asked to state their preferences on a nine-point scale of relative importance. The scales are similar to the one used in the original instrument (Saaty, 1980). According to the scale used in this study, 1: 'equally important', 2: 'equally important to somewhat important', 3: 'somewhat more important', 4: 'somewhat important to moderately important', 5: 'moderately important', 6: 'moderately important to very important', 7: 'very important', 8: 'very important to extremely important' and 9: 'extremely important'.

COMPUTATIONS AND RESULTS

The relationship between the criteria and indicators of HC are analysed using IFAHP. The details are presented as follows.

Let:

$$A = \{CrbUK, ESI, SaRK, SroTP\}$$

as an alternative,

$$C = \{T, SI, CR, KM, L\}$$

as the criteria and

$$W = \{w_1, w_2, w_3, w_4\}$$

be the 4×1 matrix, where w_i , i = 1,2, 3, 4 is the relative importance of weight of the five criteria(s). The five steps methods of IFAHP are applied to find ranking of human capital indicators.

The five criteria are compared to form a pair-wise comparison matrix (Eq. 1). Positive and negative evaluations for the criteria are given in Table 2.

Table 2: Criteria Pair-wise comparison matrix and priority

	T	SI	CR	KM	L
T	(0,0)	(0.30,0.20)	(0.70,0.10)	(0.70,0.20)	(0.60,0.40)
SI	(0.20,0.30)	(0,0)	(0.20,0.70)	(0.60,0.10)	(0.70,0.30)
CR	(0.10,0.70)	(0.70,0.20)	(0,0)	(0.30,0.40)	(0.40,0.50)
KM	(0.20,0.70)	(0.10,0.60)	(0.40,0.30)	(0,0)	(0.50,0.50)
L	(0.40,0.60)	(0.30,0.70)	(0.50,0.40)	(0.50,0.50)	(0,0)
Sum	(0.90,2.30)	(1.40,1.70)	(1.80,1.50)	(2.10,1.20)	(2.20,1.70)

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 3: Weight of the membership and non-membership for the criteria

	Priority	
Criteria	µ	v
T	0.2418	0.1173
SI	0.1874	0.1714
CR	0.1872	0.2099
KM	0.1486	0.2303
L	0.2349	0.2712

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Weights of the criteria are determined using the Eq. 2 and 3. For example, weight for criteria T is computed as:

$$T=\left[\frac{0}{0.90}+\frac{0.30}{1.40}+\frac{0.70}{1.80}+\frac{0.70}{2.10}+\frac{0.60}{2.20}\right],\left[\frac{0}{2.30}+\frac{0.20}{1.70}+\frac{0.10}{1.50}+\frac{0.20}{1.20}+\frac{0.40}{1.70}\right]$$
$$=(0.2418,0.1173)$$

Weights in term of membership and non-membership for the other criteria are computed with the similar fashion and can be summarized in Table 3.

Weights sub criteria and alternative with respect to each criterion are also computed. This paper does not provides details of membership and non-membership for the sub criteria and alternative weights.

Weighted performance for each alternative with respect to each criterion is computed using the Eq. 4. The weights of sub criteria, criteria and alternative are coherently used to obtain weighted performance. Table 4-8 show the weighted performance for alternatives with respect to each criterion.

Information from Table 4 to 8 is used to obtain composite priority. For example, the composite priority for the alternative IND1 is obtained using Eq. 5:

$$CrbUK = [0.0796+...+...+...+0.0581],$$
$$. . . . [0.0149+...+...+...+0.0581] = (0.2952, 0.1945)$$

Composite priorities for the other alternatives are computed with the similar fashion and can be summarized as Table 9.

Table 4: Priority of the membership and non-membership for the alternatives with respect to T

	Priority	
Criteria T	Membership	Non-membership
CRbUK	0.0796	0.0149
ESI	0.0560	0.0310
SaRK	0.0564	0.0319
SRoTP	0.0498	0.0394

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 5: Priority of the membership and non-membership for the alternatives with respect to SI

	Priority	
Criteria SI	Membership	Non-membership
CRbUK	0.0569	0.0407
ESI	0.0319	0.0528
SaRK	0.0572	0.0317
SRoTP	0.0414	0.0462

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 6: Priority of the membership and non-membership for the alternatives with respect to CR

	Priority	
Criteria CR	Membership	Non-membership
CRbUK	0.0516	0.0434
ESI	0.0375	0.0584
SaRK	0.0504	0.0474
SRoTP	0.0476	0.0607

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 7: Priority of the membership and non-membership for the alternatives with respect to KM

	Priority	
Criteria L	Membership	Non-membership
CRbUK	0.0489	0.0374
ESI	0.0413	0.0554
SaRK	0.0387	0.0561
SRoTP	0.0197	0.0814

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 8: Priority of the membership and non-membership for the alternatives with respect to L

	Priority	
Criteria KM	Membership	Non-membership
CRbUK	0.0581	0.0581
ESI	0.0494	0.0896
SaRK	0.0658	0.0704
SRoTP	0.0616	0.0530

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 9: Overall priority of membership and non-membership function of each alternative

	Priority	
Alternatives	Membership	Non-membership
CRbUK	0.2952	0.1945
ESI	0.2161	0.2873
SaRK	0.2685	0.2375
SRoTP	0.2202	0.2807

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 10: Overall priority of each alternative

Alternatives	Priority
CRbUK	0.4876
ESI	0.3924
SaRK	0.4525
SRoTP	0.3980

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Table 11: Ranking of each alternative

Alternative	Total score	Ranking
CRbUK	0.2818	1
ESI	0.2268	4
SaRK	0.2615	2
SRoTP	0.2300	3

CRbUK: Creating results by using knowledge, ESI: Employee' skill index, SaRK: Sharing reporting knowledge, SRoTP: Succession rate of training program

Equation 6 is utilized to obtain a single measure to represent priority for each alternative using combination operator of geometric mean. The outcome from this operation is given in Table 10.

These measures are then normalized as to fulfil the condition of sum of weights is never exceed the unity value of one. Condition stated in Eq. 7 is used to rank the normalized weights of alternatives. The final ranking for the alternatives is presented in Table 11.

Table 11 shows ranking of the Human Capital Alternatives as CRbUK⊐SaRK⊐SRoTP⊐ESI, where the symbol ⊐'is superior or preferred to'. The best alternative is creating result by using knowledge (CRbUK), followed by sharing and reporting knowledge (SaRK), succession rate of training programs (SRoTP) and lastly Employee's Skill Index (ESI).

CONCLUSION

The present millennium sees the importance of knowledge in managing organization. Managers are now realized that the value of their organization is not only depending on tangible assets but knowledge assets are equally important. Knowledge growths are not beneficial unless it 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 there are multi indicators constitute human capital thereby perpetuate various approaches in evaluation. The study presents a new approach for evaluating the pair-wise comparison and the performance score of human capital indicators using the approach based on analytic hierarchy process. The proposed new idea, intuitionistic fuzzy analytic hierarchy process was implemented in ranking the four alternatives in human capital evaluation. The new idea was a fusion of two-sided evaluation of intuitionistic fuzzy sets with pair-wise comparison of analytic hierarchy process. The computation results show that the alternative 'creating result by using knowledge' is the most important indicator for Malaysian human capital. The organization must pay full attention to creating results using the power of knowledge. The intuitionistic fuzzy analytic hierarchy process could be applied to different organization climate in future research.

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