Project Experts' Evaluation Study Based on Analytic Hierarchy Process

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Abstract— To assure justice and fair of scientific and technological project evaluation, avoiding the corrupt transaction in the process of project evaluation, it is necessary to evaluate the experts' performance with a scientific method. The main criteria such as publications, patents and awards, international effects, domestic effects, social effects and etc that affect the project evaluation were analyzed. In order to avoid the effect of individual expert subjective judgment and favouritism on the project evaluation, analytic hierarchy process (AHP) is introduced. AHP is widely used in comparing the options in order to achieve the goal. For the application of AHP in project evaluation, the 1 Malaysia values such as the culture of excellence, endurance, humility, acceptance, loyalty, meritocracy and integrity are chosen to be the criteria. This paper presents the theory of the alternative method to evaluate the scientific and technological project. The study provides a scientific and reliable method of the project experts' evaluation.

Keywords: Analytic Hierarchy Process (AHP), 1 Malaysia, Scientific and technological project selection, TOPSIS

1. Introduction

Current research on technology strategy focuses on the content and type of technology planning, and the relationship between technology strategy and other strategies; fewer studies include the implementation of technology strategy at execution level, and the integration between macro- and micro- level factors and existing technological capabilities. A good technology strategy can guide enterprises' to choose the right development projects with external requirements and internal constraints.

The concept of 1Malaysia aspires to strengthen relationships among races and ensures Malaysians to understand and practise things that place national interest as priority. Our prime minister, Datuk Seri Najib Tun Razak emphasizes on building a nation depends on the sharing of values such as integrity, ability, dedication and etc. The values can be implemented in scientific and technological projects' evaluation.

2. AHP Method

AHP, also known as the Analytical Hierarchy Process is multiple criteria decision making method which was put forward by Prof T. L. Saaty of Pittsburgh University in 1970s [1]. The general idea in the AHP method is to make the pair wise comparisons, both of the alternatives with respect to the criteria (scoring), and criteria to estimate the criteria weights (weighting) [2]. AHP technique acts as a decision maker systematically evaluating several data or elements by comparing one and another at the same time. It judges the elements relative meaning and importance based on the numerical values process by this technique. The numerical value represented the weight or priority of each elements of the hierarchy.

According to Cheng and Li [3], there were two basic applications where one is assign weights to a set of predetermined elements and make a decision out of several scenarios or alternatives, while the second one is to prioritize the elements in order to identify the key elements. In the end of the calculation, the approximate weight vector of the elements can be determined. The AHP method can be expressed in series of step as shown in Figure 1.

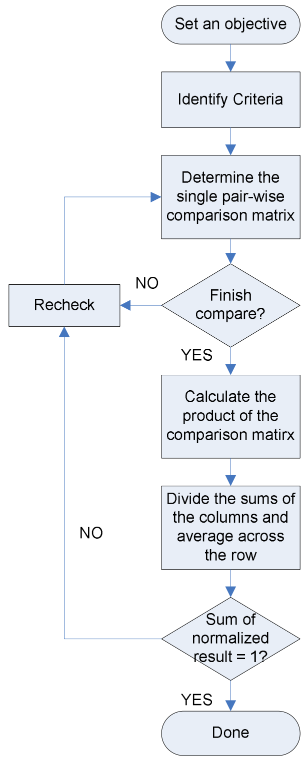

Figure 1: Flowchart of the AHP solution procedure

3. TOPSIS Method

TOPSIS is known as the "Technique for Order Preference by Similarity to Ideal Solution". This method is a unique technique to identify the ranking of all alternatives considered. In the TOPSIS method, the decision making matrix and weight vector are determined as crisp values and a positive ideal solution (PIS) and a negative ideal solution (NIS) are obtained from the decision matrix [4]. In another word, PIS is a set of best value of criteria while NIS is a set of worst values achievable of criteria. This method is applied to make wide-ranging evaluation of samples where it measured the distances between index value vector of each sample and ideal solution along with the negative ideal solution of the comprehensive evaluation [5].

The TOPSIS method can be expressed in series of steps as listed below.

1) Identifying the alternatives over criteria involved to form a decision matrix.
2) Constructing a set of normalized decision matrix using eq. (1).

$$r_{ij} = \frac{x_{ij}}{\sqrt{(\sum x^2{}_{ij})}} \quad ,\text{for } i = 1, \ldots, m;\ j = 1, \ldots, n \qquad (1)$$

3) Constructing a set of weight normalized decision matrix with criteria weight, w_j provided.
4) Identifying the ideal alternatives and negative ideal alternatives.
   - Ideal solution.

   $$PIS= \{ v_1^*, \ldots, v_n^* \}, \text{ where } V_J^* = \{ \max(v_{ij}) \text{ if } j \in J; \min(v_{ij}) \text{ if } j \in J' \} \qquad (2)$$

   - Negative ideal solution.

   $$NIS= \{ v_1^{'}, \ldots, v_n^{'} \}, \text{ where } V^{'} = \{ \min(v_{ij}) \text{ if } j \in J; \max(v_{ij}) \text{ if } j \in J' \} \qquad (3)$$

5) Calculate the separation measurement of each alternative in s_i for ideal solution and sn_i for negative ideal solution.
6) Calculate the relative closeness to ideal solution using the eq. (4)

   $$RATIO = \frac{sn_i}{sn_i + s_i} \qquad (4)$$

7) Ranked the alternatives starting from the value that closest to 1.

The iteration solution procedure is summarized in a flowchart in Figure 2.

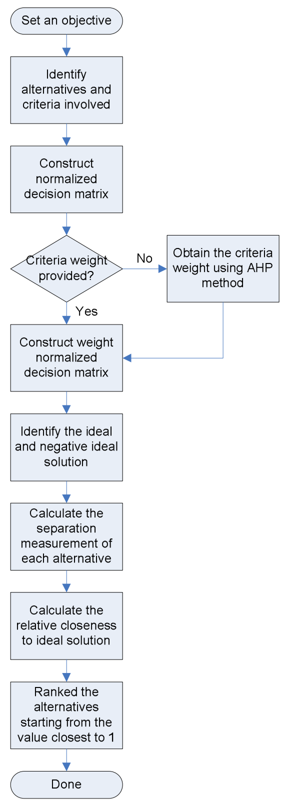

Figure 2: Flowchart of TOPSIS solution procedure

Hwang and Yon [6] are the first who introduce the TOPSIS method. Hwang and Yon describe multiple decisions making as follows: multiple decision making is applied to preferable decision (such as assessment making priority and choice) between available classified alternatives over the multiple attributes or criteria. It assumes that each criterion require to be maximized or minimized. Therefore, the ideal positive and negative values of each criterion are identified, and each alternative judge against this information.

It is note that, in this typical multiple criteria decision making (MCDM) approaches, weights of attributes reflect the relative importance indecision making process. Each evaluation of criteria entails diverse opinions and meanings. Hence assumption that each evaluation criterion is equally importance is prohibited. [7].

TOPSIS method consists of two artificial alternatives hypothesis which are ‘Ideal Alternative’ and ‘Negative Ideal Alternative’. ‘Ideal Alternative’ represents the best level of all attributes considered while the 'Negative Ideal Alternative' represented the worst attributes value. With these two hypotheses, sets of calculations using eigenvector, square rooting and summations to obtain a relative closeness value of the criteria tested. These values of relative closeness, TOPSIS ranked the whole system by selecting the highest value of the relative closeness as the best attributes in the system.

4. Numerical Example

From the scientific and technological project selection, international effects and social effects are the two criteria involved in the selection. Out of the values listed in 1 Malaysia concept listed, six values are selected, which are the culture of excellence, endurance, humility, acceptance, meritocracy and integrity as the sample in this paper. These six areas were determined based on their estimated weightage, the usage of the values in particular scientific and technological area, and the important of the values to the whole selection process. As discuss in previous, all values that are chosen shall be those values that have higher international effects and social effects, and projects which were less important to the international effects and the social effects that can be rejected. Besides that, theoretically, after applying the TOPSIS method onto the selection scheme, the projects that shall be selected would be the projects that having higher international effects and higher social effects during the operations.

Figure 3 below shows an example of data obtained from a scientific and technological project. It consists of value, international effects and social effects which attribute to the project selection. The value was defined as the alternatives while the international effects and the social effects taken as the attribute or criteria in TOPSIS method for calculations. Below shows a set of selection data for load shedding purposes.

Alternative	International effects	Social effects
the culture of excellence	a1=0.6	a2=1.088
endurance	b1=27.4	b2=28.83
humility	c1=1.3	c2=2.328
acceptance	d1=21.5	d2=22.63
meritocracy	e1=17.4	e2=26.57

integrity	f1=20.6	f2=50.4

Figure 3: Selection Data for Project Evaluation Purpose

Step1:

Identify the data for alternatives over criteria to form a set of decision matrix. Note that, criteria that need to be minimized in the selection shall be placed at the last position for easier calculations in TOPSIS application. Since the objective of selection scheme is to minimize the favouritism when a selection is vulnerable to the human factors, hence in arranging the criteria before forming the decision matrix, the international effect is placed as the last criteria. This is clearly shown in Figure 4 below. Before that, a few variable assumptions shall be assumed in this context.

- Variable m as the alternatives (options), variable n as the attributes/criteria and the score of each option with respect to each criterion.
- Let x_{ij} score of option i with respect to criterion j
- Let the matrix, $X = (x_{ij})$ m×n matrix.
- Let the variable J be the set of benefit attributes or criteria (more is better)
- Let the variable J' be the set of negative attributes or criteria (less is better)

$$Let\ m, Alternative = \left(\begin{matrix} excellence \\ endurance \\ humility \\ acceptance \\ meritocracy \\ integrity \end{matrix} \right) \text{ and } n, criteria = \begin{pmatrix} a1 & a2 \\ b1 & b2 \\ c1 & c2 \\ d1 & d2 \\ e1 & e2 \\ f1 & f2 \end{pmatrix}$$

Therefore, criteria matrix form, $\begin{pmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \\ x_{31} & x_{32} \\ x_{41} & x_{42} \\ x_{51} & x_{52} \\ x_{61} & x_{62} \end{pmatrix} = \begin{pmatrix} a1 & a2 \\ b1 & b2 \\ c1 & c2 \\ d1 & d2 \\ e1 & e2 \\ f1 & f2 \end{pmatrix}$

$$\begin{pmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \\ x_{31} & x_{32} \\ x_{41} & x_{42} \\ x_{51} & x_{52} \\ x_{61} & x_{62} \end{pmatrix} = \begin{pmatrix} 0.6 & 1.088 \\ 27.4 & 28.83 \\ 1.3 & 2.328 \\ 21.5 & 22.63 \\ 17.4 & 26.57 \\ 20.6 & 50.4 \end{pmatrix}$$

Figure 4: Determine the alternatives over the criteria to form a decision matrix

Step2:

In step 2, it is to obtain the normalized decision matrix by using the decision matrix form in step 1. In order to normalize the set of data, each data of the system shall be divided with the square root of the summation of each data with square by column.

As shown in Figure 5, the criteria is being squared and followed by the square root of summation by column. This is actually a step to obtain the normalized ratio of the each column, Y and Z before the score of the criteria are being divided with it. These normalized values are important to obtain because tit represents the overall ratio of the data involve.

Arithmetic of the square of original values

$$\overrightarrow{Criteria^2} = \begin{pmatrix} 0.36 & 1.184 \\ 750.76 & 831.169 \\ 1.69 & 5.42 \\ 462.25 & 512.117 \\ 302.76 & 705.965 \\ 424.36 & 2.54 \times 10^3 \end{pmatrix}$$

$$\left(\overrightarrow{Criteria^2}\right)^T = \begin{pmatrix} 0.36 & 750.76 & 1.69 & 462.25 & 302.76 & 424.36 \\ 1.184 & 831.169 & 5.42 & 512.117 & 705.965 & 2.54 \times 10^3 \end{pmatrix}$$

$$\binom{Y}{Z} = \sqrt{\left(\overrightarrow{Criteria^2}\right)^T \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{pmatrix}} \quad \binom{Y}{Z}^T = (44.07 \quad 67.764)$$

Normalized data:

$$\begin{pmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \\ r_{31} & r_{32} \\ r_{41} & r_{42} \\ r_{51} & r_{52} \\ r_{61} & r_{62} \end{pmatrix} = \begin{pmatrix} \frac{x_{11}}{Y} & \frac{x_{12}}{Z} \\ \frac{x_{21}}{Y} & \frac{x_{22}}{Z} \\ \frac{x_{31}}{Y} & \frac{x_{32}}{Z} \\ \frac{x_{41}}{Y} & \frac{x_{42}}{Z} \\ \frac{x_{51}}{Y} & \frac{x_{52}}{Z} \\ \frac{x_{61}}{Y} & \frac{x_{62}}{Z} \end{pmatrix}, \begin{pmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \\ r_{31} & r_{32} \\ r_{41} & r_{42} \\ r_{51} & r_{52} \\ r_{61} & r_{62} \end{pmatrix} = \begin{pmatrix} 0.014 & 0.016 \\ 0.622 & 0.425 \\ 0.029 & 0.034 \\ 0.488 & 0.334 \\ 0.395 & 0.392 \\ 0.467 & 0.743 \end{pmatrix}$$

Figure 5: Normalized decision matrix (TOPSIS)

<u>Step3:</u>

In this step, the weight decision matrix is build by multiplying these normalized values (obtained in step 2) with their corresponding weight, w_j. However, in this study, the corresponding weight is not provided, hence the Analytical Hierarchy Process (AHP) technique is applied in order to obtain the weight for each criterion. Figure 6 shows the series of calculations using the AHP technique. Based on the figure below, assume the variable 'A' as the single pair wise comparison matrix for the EOL and MW while variable 'B" as their normalized values. Since this step is applied to obtain the corresponding weight for EOL and MW, hence the summation of the overall scores of these criteria is needed.

Firstly, determine the single pair-wise comparison matrix and then calculate the product of the comparison matrix. Next divide the sums of the column and average across the row. The value achieved is then named as W_1 and w_2 as shown in Figure 6 and Figure 7.

Sum of criteria

$$International\ effect = a1 + b1 + c1 + d1 + e1 + f1$$

$$International\ effect = 88.8$$

$$Social\ effect = a2 + b2 + c2 + d2 + e2 + f2$$

$$Social\ effect = 131.846$$

Identify single pair-wise comparison matrix

$$A = \begin{pmatrix} \frac{International\ effect}{International\ effect} & \frac{Social\ effect}{International\ effect} \\ \frac{International\ effect}{Social\ effect} & \frac{Social\ effect}{Social\ effect} \end{pmatrix}$$

$$A^2 = \begin{pmatrix} 2 & 2.97 \\ 1.347 & 2 \end{pmatrix}$$

Total of column by column, C1 and C2,

$$(C1 \quad C2) = (1 \quad 1)A^2$$

$$(C1 \quad C2) = (3.347 \quad 4.97)$$

Normalized each column, B,

$$B = \begin{pmatrix} \frac{2}{C1} & \frac{2.97}{C2} \\ \frac{1.347}{C1} & \frac{2}{C2} \end{pmatrix}$$

$$B = \begin{pmatrix} 0.598 & 0.598 \\ 0.402 & 0.402 \end{pmatrix}$$

Figure 6: Normalized decision matrix (AHP)

In Figure 7, the average value across the row represents the weighting for the criteria tested. The variable W_1 represent weight for the International effect while the variable W_2 represent the Social effect criteria. From the calculation, the results pointed up that the International effect is more important where it has the higher weight. However, this weight will be then carried to TOPSIS method for further calculations to obtain the ranking for all the alternatives tested.

Averageof row by row, W_1 and W_2

$$W_1 := \frac{1}{2}(0.598 + 0.598)$$

$$W_2 := \frac{1}{2}(0.402 + 0.402)$$

$$W_1 = 0.598$$

$$W_2 = 0.402$$

Figure 7: The weighting of International effect and Social effect

The variable W_1 and W_2 is then used to multiply with the normalized decision matrix (TOPSIS) in Figure 5 to obtain the weight decision matrix.

$$V_{ij} := W_j \cdot r_{ij}$$

$$\begin{pmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \\ v_{31} & v_{32} \\ v_{41} & v_{42} \\ v_{51} & v_{52} \\ v_{61} & v_{62} \end{pmatrix} := \begin{pmatrix} r_{11} \cdot W_1 & r_{12} \cdot W_2 \\ r_{21} \cdot W_1 & r_{22} \cdot W_2 \\ r_{31} \cdot W_1 & r_{32} \cdot W_2 \\ r_{41} \cdot W_1 & r_{42} \cdot W_2 \\ r_{51} \cdot W_1 & r_{52} \cdot W_2 \\ r_{61} \cdot W_1 & r_{62} \cdot W_2 \end{pmatrix}$$

$$\begin{pmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \\ v_{31} & v_{32} \\ v_{41} & v_{42} \\ v_{51} & v_{52} \\ v_{61} & v_{62} \end{pmatrix} = \begin{pmatrix} 8.142 \times 10^{-3} & 6.452 \times 10^{-3} \\ 0.372 & 0.171 \\ 0.018 & 0.014 \\ 0.292 & 0.134 \\ 0.236 & 0.158 \\ 0.28 & 0.299 \end{pmatrix}$$

Figure 8: Weight Decision Matrix

Step4:

In this case, the W_{11}, W_{21}, W_{31}, W_{41}, W_{51}, and W_{61} is belong to the benefit criteria while for the W_{12}, W_{22}, W_{32}, W_{42}, W_{52}, and W_{62} is belong to the non-beneficial criteria. Therefore, by using the Eq. (2) and Eq. (3), the ideal alternatives and negative ideal alternatives solution can be determine as:

$$\text{PIS} = \{0.372, 6.452 \cdot 10^{-3}\}$$

$$\text{NIS} = \{8.142 \times 10^{-3}, 0.299\}$$

Figure 9: Positive Ideal Solution and Negative Ideal Solution

Step5:

Calculate the distance between the alternatives with the positive and negative ideal solutions using Eq. (5) and Eq. (6).

For Positive Ideal Solution

$$SI := \sqrt{\sum \left(v_{ij} - PIS\right)^2} \tag{5}$$

For Negative Ideal Solution

$$SNI := \sqrt{\sum \left(v_{i} - NIS\right)^2} \tag{6}$$

The distance measurements can is illustrated in Figure 10 for the Positive Ideal Solution and Figure 11 for the Negative Ideal Solution.

The separation from the ideal alternative

$$SI := \sqrt{\sum \left(v_{ij} - PIS\right)^2} \quad i = 1,\ldots,m$$

$$SI := \begin{bmatrix} \left[\sqrt{(v_{11} - 0.372)^2}\right] & \left[\sqrt{(v_{12} - 6.452\times10^{-3})^2}\right] \\ \left[\sqrt{(v_{21} - 0.372)^2}\right] & \left[\sqrt{(v_{22} - 6.452\times10^{-3})^2}\right] \\ \left[\sqrt{(v_{31} - 0.372)^2}\right] & \left[\sqrt{(v_{32} - 6.452\times10^{-3})^2}\right] \\ \left[\sqrt{(v_{41} - 0.372)^2}\right] & \left[\sqrt{(v_{42} - 6.452\times10^{-3})^2}\right] \\ \left[\sqrt{(v_{51} - 0.372)^2}\right] & \left[\sqrt{(v_{52} - 6.452\times10^{-3})^2}\right] \\ \left[\sqrt{(v_{61} - 0.372)^2}\right] & \left[\sqrt{(v_{62} - 6.452\times10^{-3})^2}\right] \end{bmatrix}$$

$$SI = \begin{pmatrix} 0.364 & 4.469\times10^{-7} \\ 2.02\times10^{-4} & 0.165 \\ 0.354 & 7.352\times10^{-3} \\ 0.08 & 0.128 \\ 0.136 & 0.151 \\ 0.092 & 0.292 \end{pmatrix}$$

$$\begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \end{pmatrix} := \sqrt{SI \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix}}$$

$$\begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \end{pmatrix} = \begin{pmatrix} 0.603 \\ 0.406 \\ 0.601 \\ 0.456 \\ 0.536 \\ 0.62 \end{pmatrix}$$

Figure 10: The Distance measurement for separation Positive ideal Solution (SI)

The separation from the negative ideal alternative

$$SNI := \sqrt{\sum (v_i - NIS)^2} \qquad i = 1,...,m$$

$$SNI := \begin{bmatrix} \left[\sqrt{\left(v_{11} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{12} - 0.299\right)^2}\right] \\ \left[\sqrt{\left(v_{21} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{22} - 0.299\right)^2}\right] \\ \left[\sqrt{\left(v_{31} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{32} - 0.299\right)^2}\right] \\ \left[\sqrt{\left(v_{41} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{42} - 0.299\right)^2}\right] \\ \left[\sqrt{\left(v_{51} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{52} - 0.299\right)^2}\right] \\ \left[\sqrt{\left(v_{61} - 8.142 \times 10^{-3}\right)^2}\right] & \left[\sqrt{\left(v_{62} - 0.299\right)^2}\right] \end{bmatrix}$$

$$SNI = \begin{pmatrix} 4.387 \times 10^{-7} & 0.293 \\ 0.364 & 0.128 \\ 9.498 \times 10^{-3} & 0.285 \\ 0.284 & 0.165 \\ 0.228 & 0.141 \\ 0.271 & 1.413 \times 10^{-4} \end{pmatrix}$$

$$\begin{pmatrix} sn_1 \\ sn_2 \\ sn_3 \\ sn_4 \\ sn_5 \\ sn_6 \end{pmatrix} := \sqrt{SNI \cdot \begin{pmatrix} 1 \\ 1 \end{pmatrix}}$$

$$\begin{pmatrix} sn_1 \\ sn_2 \\ sn_3 \\ sn_4 \\ sn_5 \\ sn_6 \end{pmatrix} = \begin{pmatrix} 0.541 \\ 0.701 \\ 0.543 \\ 0.67 \\ 0.608 \\ 0.521 \end{pmatrix}$$

Figure 11: The Distance measurement for separation Negative Ideal Solution (SNI)

<u>Step6:</u>

Using Eq. (4), the relative closeness coefficient, RC can be obtained. The numerical value of each alternative will be in between 0 to 1. Based on TOPSIS method, the higher the numerical achieve, the higher the possibility or the best alternatives among all. Therefore, *endurance* shall be the first value to be taken into consideration whenever there is any selection process occurring.

$$\begin{pmatrix} excellence \\ endurance \\ humility \\ acceptance \\ meritocracy \\ integrity \end{pmatrix} = \begin{pmatrix} \frac{sn_1}{sn_1 + s_1} \\ \frac{sn_2}{sn_1 + s_1} \\ \frac{sn_3}{sn_1 + s_1} \\ \frac{sn_4}{sn_1 + s_1} \\ \frac{sn_5}{sn_1 + s_1} \\ \frac{sn_6}{sn_1 + s_1} \end{pmatrix}$$

$$\begin{pmatrix} excellence \\ endurance \\ humility \\ acceptance \\ meritocracy \\ integrity \end{pmatrix} = \begin{pmatrix} 0.473 \\ 0.613 \\ 0.474 \\ 0.585 \\ 0.531 \\ 0.455 \end{pmatrix}$$

Figure 12: The Relative closeness Coefficient

Step7:

The corresponding ranking of six possible values is tabulated in Figure 13. The ranking of the alternatives s based on the value that closest to 1. The first position represented the first values to be taken based on the justification.

$$Rating = endurance > acceptance > meritocracy > humility > excellence > integrity$$

$$\begin{pmatrix} excellence \\ endurance \\ humility \\ acceptance \\ meritocracy \\ integrity \end{pmatrix} = \begin{pmatrix} 0.473 \\ 0.613 \\ 0.474 \\ 0.585 \\ 0.531 \\ 0.455 \end{pmatrix} \begin{pmatrix} 5th \\ 1st \\ 4th \\ 2nd \\ 3rd \\ 6th \end{pmatrix}$$

Figure 13: Alternatives ranking start from the value closest to 1

5. Analysis

In this paper, a new method in finding weight has been applied. The Analytic Hierarchy Process (AHP) is used to obtain the criteria weight while the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is used to rank the selected values into series of sequences. In AHP method, the weight represents the priority of each criterion. From the calculations, the higher the value of weight calculated (W_{AHP}), the higher the priority of one criteria. The numerical weight or priority derived from AHP allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. These values were then taken as their weight for TOPSIS usage.

6. Conclusions

The procedure of extended TOPSIS is explained in seven steps. Within the steps, it includes the normalized rules of combination as the pre-operation of external collection, defining the PIS and NIS, calculating the separation measurements of each alternative from total PIS and NIS, computing the closeness coefficient of each alternative and the ranking of the preference order for group.

This paper presents an idea to combine the TOPSIS multi-criteria decision making with the 1 Malaysia values in scientific and technological project evaluation. This method is an agent in searching the best set of values to be selected in order to select the best project without bias or subjective judgments.

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