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SELECTING STUDENTS FROM LOW INCOME FAMILY USING ANALYTICAL HIERARCHY PROCESS BASED ON LINGUISTIC HEDGES

(Memilih Pelajar daripada Keluarga Berpendapatan Rendah Menggunakan Proses Hierarki Analisis Berasaskan Pagaran Linguistik)

ZAMALI TARMUDI, UNG LING-LING, NASRAH NAHARU & TAMMIE C. SAIBIN

ABSTRACT

In this paper, we propose a new method for selecting students from low income family, namely *Mengubah Destini Anak Bangsa* (MDAB) programme by analytical hierarchy process based on linguistic hedges. It focuses on utilising the linguistic hedges for decision-makers (DMs) to make their judgement for weighting purposes. Two linguistic hedges, the *concentration* and *dilation* are used to measure the importance of relative weight for each criterion. Meanwhile, the group of DMs viewpoints is used to build the membership functions towards deriving the entire criterion performance scores. Then, the maxmin operator and sorting the results by descending order are applied to determine the best alternative and ranking process, respectively. A numerical example related to Universiti Teknologi MARA (UiTM) MDAB students' selection is presented to demonstrate the applicability of the proposed method. It is found that the method is successful in dealing with situations which are relevant to the university concern, thus can facilitate the DMs to make a decision in a simple and systematic manner.

Keywords: analytical hierarchy process (AHP); concentration; dilation; linguistic hedges; *Mengubah Destini Anak Bangsa* (MDAB); students selection

ABSTRAK

Dalam makalah ini, diusulkan suatu kaedah untuk pemilihan pelajar dalam kalangan keluarga berpendapatan rendah atau dikenali sebagai program Mengubah Destini Anak Bangsa (MDAB) secara proses hierarki analisis berasaskan pagaran linguistik. Perbincangan terfokus kepada memanfaatkan pagaran linguistik untuk pembuat keputusan menentukan pemberat sesuatu atribut dalam proses penilaian. Dua jenis pagaran linguistik yang dinamai *konsentrasi* dan *dilasi* diguna untuk mengukur kepentingan pemberat relatif setiap kriterium kajian. Pendapat pembuat keputusan berkumpulan pula diguna untuk membina fungsi-fungsi keahlian bagi tujuan mendapatkan keseluruhan skor prestasi. Seterusnya, pengoperasi minmaks dan proses menyusun secara menurun dilakukan masing-masing untuk menentukan pilihan terbaik dan proses pemangkatan. Suatu contoh empirikal berkaitan dengan proses pemilihan pelajar MDAB di Universiti Teknologi MARA (UiTM) diguna pakai untuk menunjukkan kebolehgunaan kaedah usulan. Hasilnya menunjukkan kaedah ini berjaya menangani situasi ketakpastian yang wujud dalam proses pemilihan pelajar seperti yang diperlukan oleh UiTM. Di samping itu ia memberi manfaat kepada pembuat keputusan untuk membuat keputusan secara bersistematik dan lebih mudah.

Kata kunci: proses hierarki analisis (PHA); *konsentrasi*; *dilasi*; pagaran linguistik; Mengubah Destini Anak Bangsa (MDAB); pemilihan pelajar

1. Introduction

Malaysia got its independence in the year 1957, and in 1963, Sarawak and Sabah joined Malaysia. Since then, Malaysia has successfully transforming itself from a poor country into a middle-income nation (Altharthi 2012; Hatta & Ali 2013). According to Oxford dictionary, poverty is defined as the state or condition of having little or no money, goods, or means of support; or condition of being poor. According to to the World Bank Organisation, poverty is usually measured based on income. A person will be considered poor if his or her income falls below the minimum level to meet basic necessities. According to Hatta and Ali (2013), based on a research conducted by Department of Statistics (2011), Malaysia has 3.7% overall poverty rate compared to 1970, where its poverty rate was 49.3%. However, among the states in Malaysia, Sabah (19.7%) is the highest poverty level followed by Perlis (6.3%). Therefore, government authorities have executed many programmes focusing on Sabah and Sarawak to combat the poverty.

Hatta and Ali (2013) stated that the evolution of welfare regime imposed by Malaysian government is to combat poverty. From 2003 until present, authorities have been focusing on agricultural sectors, small medium enterprises, increased health facilities and also strengthening student's welfare. It is clearly shown that the authorities combating the poverty by equipping students with quality of education. Research done by Bonal (2007) concluded that no educational policy can be effective if it fails to take into account the effects of poverty on education. It is strongly believed that education can alleviate the socio-economy status of a community. Tilak (2002) emphasised the importance of education to promote rural poor communities to higher level of social, cultural and occupational standing. Hatta and Ali (2013) also recommend giving the unfortunate the chance to study by equipping them with technical education and vocational training to increase their qualifications. A research done by Rolleston (2011) to find the relationship between educational access and poverty reduction, a case in Ghana, confirmed that, a well educated person will improve the social welfare especially the mobility of their families to get out from poverty environment. But then again, the poor community is already struggling to lay food on the table everyday, what more to say to provide education to the young. This disadvantaged group always fall at the back of their peer from urban or from wealth of family in terms of academic performance. This is mainly due to the inability to access to adequate resources and material to help them to perform better in academic compared to their peers at the urban.

The education system is to be blamed as well, as Malaysian higher education system select students mainly based on the academic performance. This has made things even worst as the poor students from the rural area are left out as their academic performance is usually bad. Students from Sabah normally scored the lowest which correlate to the poverty range in Malaysia (Woo 2011; Khoo 2012).

Acknowledging this issue, UiTM Sabah Branch has designed an approach to cater students from poor income family, so that they will not be left out in securing a seat in pursuing studies in higher education at UiTM. The designed method will consider their family background, for example the family monthly income and number of siblings as parameters are considered in the selection process.

Researches are carried out to optimise selection of candidates to higher education. A research was done by McCallum *et al.* (2006), using interview score sheet to select nursing student, Wimatsari *et al.* (2013) used fuzzy multiattribute decision making technique for using Order Preference by Similarity to Ideal Solution (TOPSIS) to select scholarship recipients, and Deni *et al.* (2013) used fuzzy multi attribute decision making by Simple Additive Weighting (SAW) method to select high achievers of students.

Based on the above literatures, existing research very rarely explores and utilises the AHP based on the *dilation* or *concentration* power of linguistic hedges in decision-making environment, particularly for student's selection problem. It is believed that the proposed method enables dealing with UiTM concern as related to MDAB selection problem. To do so, this paper is structured as follows: In Section 2 the brief problem identification is elaborated, while in Section 3 and 4 the preliminary of the background theory and the proposed method are discussed, respectively. A numerical example is also provided to illustrate the application of the proposed method in Section 5, before the conclusion is pointed out in Section 6.

2. Problem Identification

UiTM started the MDAB programme (Mengubah Destini Anak Bangsa) since July 2010, with the goal of reaching out to the native students from rural areas, by offering them an opportunity to improve their social life through education. The programme manages to get impressive respond from the community which instigated massive applications at a time. The admission procedure takes longer time and selection process becomes more complicated. For example two applicants with the same score in academic performance but the first candidate has 3 siblings with RM800 per month as family income while the second candidate has 2 siblings but with RM1000 per month as family income. The manual system fail to classify these applications efficiently, and it requires many man power to do so. Problem in selection process also arises mainly due to financial constraints, time constraints and limited seat offered to the candidates. The newly proposed method will ease the procedure by providing efficient classification on complex variables involved in the selection criteria.

3. Preliminary: Theoretical Background

For reference purposes, the theoretical background is briefly reviewed from Cheng *et al.* (1999), Cox (1994), Zimmermann (1991), Kaufmann and Gupta (1985) and Zadeh (1975). These basic definitions and the concepts will be used throughout this paper until otherwise stated.

Definition 1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterised by a membership function $\mu_{\tilde{A}}(x)$ that takes the values in the interval [0, 1]. It can be denoted as follows:

$$\tilde{A} = \{(\mu_{\tilde{A}}(x)/x); x \in X\}$$

Definition 2. A triangular fuzzy number (TFN) $\tilde{A}$ is a fuzzy set in $\mathbb{R}$ denoted by a triplet (a,b,c) such that its membership function $\mu_{\tilde{A}}(x)$ is defined as:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < a, \\ \dfrac{x-a}{b-a}, & a \le x \le b, \\ \dfrac{x-c}{b-c}, & b \le x \le c, \\ 0, & x > c \end{cases} \tag{1}$$

Definition 3. A linguistic hedge or a modifier is an operation that modifies the meaning of a term, more generally of a fuzzy set. If $\tilde{A}$ is a fuzzy set then the modifier k generates the (composite) term $\tilde{B} = k\left(\tilde{A}\right)$. The modifiers used frequently are:

Concentration

$$\mu_{con(\tilde{A})}(x) = \left[\mu_{\tilde{A}}(x)\right]^{w}, \text{ where } w > 1 \tag{2}$$

Dilation

$$\mu_{dil(\tilde{A})}(x) = \left[\mu_{\tilde{A}}(x)\right]^{1/w}, \text{ where } w > 1 \tag{3}$$

Definition 4. The linguistic hedges and their approximate meanings are specifically classified as shown in Table 1.

Table 1: The hedge values of the specific dilation and concentration

Linguistic hedges	Meaning	Hedge type	Hedge values (w)
Extremely A	Intensify a fuzzy region	Concentration	$[\mu_{extremely\ A}(x)]^3$
Very A	Contrast intensification	Concentration	$[\mu_{very\ A}(x)]^2$
A (i.e., no hedges)	-	-	$\mu_A(x)$
Usually A	Contrast diffusion	Dilation	$[\mu_{usually\ A}(x)]^{1/2}$
Somewhat A	Dilate a fuzzy region	Dilation	$[\mu_{s.what\ A}(x)]^{1/4}$
Between above linguistic hedges	Intensify/contrast/dilate	Concentration/ dilation	between above two hedges value range

Source: Cox (1994)

4. Our Proposed Approach

4.1. *The AHP-based Linguistic Hedges*

Analytic hierarchy process (AHP) introduced by Saaty (1980) is one of the widely used methods in multi-criteria decision making (MCDM) problems. It offers systematic approaches to alternative selection and justification problem by using the hierarchical structure analysis and concepts of fuzzy set theory (Bozbura *et al.* 2007). Recent researches have utilised the Saaty AHP method to solve various MCDM problems (Yurdakul 2002; Scholl *et al.* 2005; Bozdag *et al.* 2003; Yaakob & Kawata 1999; Drigas *et al.* 2004). In Saaty AHP, the unique technique is the pairwise comparison matrix to compare between criteria and alternatives to derive the weighted values. The crisp 1 – 9 scale is used in earlier version of AHP for pair-wise comparison assessment. However, in real application, the decision makers (DMs) prefer a flexible judgement rather than sharp numerical values in assessing process. For example, the numeric value such as 7, 5 or 3 and so on, cannot represent efficiently in pair-wise comparison process compared with the approximate values. For this reason, many researchers found that the classical AHP approach has some shortcomings (Bozbura *et al.* 2007; Cheng *et al.* 1999).

One of the shortcomings concern is that the yield may not satisfied the result due to the nature of information being usually subjective and intangible. Although the AHP approach has attracted criticism for certain aspects, it is still very popular due to its ability to structure a complex, multi-person and multi-attribute problem hierarchically. It also allows one to investigate each level of the hierarchy separately, combining the results as the analysis progresses (Fuh & Hui 2005). With regard to the above shortcoming, the linguistic hedges are utilised to derive the importance of the relative weights for each criterion in the decision process.

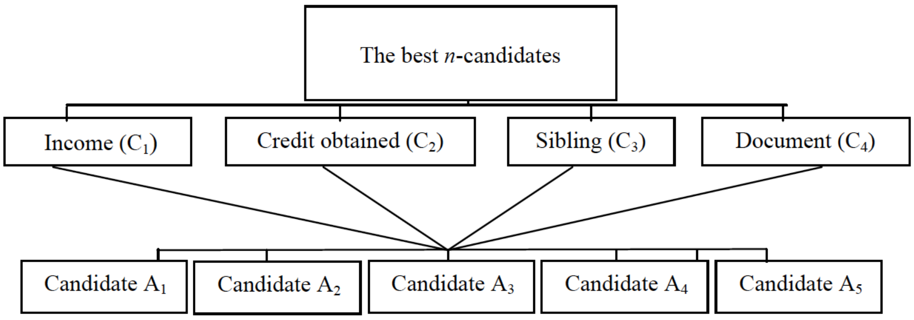

Figure 1 : Hierarchical structure for evaluating student's application

4.2. *The Algorithm and Its Application for Selecting MDAB Students*

The selection of MDAB students is a multiple attributes decision-making problem. Firstly, the actual problems are transformed into a hierarchical structure (see Fig. 1). As we can see, the structure has at least three levels of hierarchy which comprises the objective or goal of the study at the first level, followed by some related criterion to support the problems' objective in the second level and the alternative lies in the third level. For the performance datasets, we consult relevant expert's viewpoint for actual situation to build the membership functions for the first three criteria (i.e. parent income, credit obtained and number of siblings) as given in Table 2. Meanwhile, the last criterion (i.e. document status) can be derived directly from definition in Table 3. Thus, we use AHP based on linguistic hedges to evaluate each attribute towards choosing the best *n*-candidates.

Table 2: The membership functions for the first three criteria

Criteria	*Membership function*	
Parent Income (C_1)	$\mu_{\tilde{C}_1}(x) = \begin{cases} 0 & ; \quad 3000 \le x \\ 1 - \dfrac{x}{3000} & ; \quad 3000 > x \end{cases}$	(4)
Number of credits obtained (C_2)	$\mu_{\tilde{C}_2}(x) = \begin{cases} \dfrac{x-2}{5}; & 3 \le x < 5 \\ \dfrac{x}{10}; & 5 \le x < 10 \\ 1 \quad ; & x \ge 10 \end{cases}$	(5)
Number of siblings (C_3)	$\mu_{\tilde{C}_3}(x) = \begin{cases} 0.5 & ; \quad 1 \le x \le 3 \\ 0.75 & ; \quad 3 < x \le 6 \\ 1 & ; \quad x > 6 \end{cases}$	(6)

Table 3: The four difference definitions of document status (C_4)

Membership values	Description
0	If the candidate is *Bumiputera* but does not provide all necessary documents (DS_1) (i.e., identification card, birth of certificate, and pay slip/certified monthly income statement for applicant and their parent)
0.3	If the candidate is *Bumiputera* but does not provide both relevant documents (DS_2) (i.e., identification card or birth of certificate and pay slip/certified monthly income statement for applicant and their parent)
0.7	If the candidate is *Bumiputera* but does not provide parent's pay slip/certified monthly income statement (DS_3).
1	If the candidates is *Bumiputera* with complete documents (DS_4)

Note: Bumiputera~native

For the easy computing, we summarise the algorithm for selecting MDAB students by AHP based on linguistic hedges as follows:

Step 1: Decompose the problem (identify goal, criteria, and alternatives) and construct the hierarchical structure as shown in Fig. 1.

Step 2**:** Determine all the scores (PS_{mxn}) as corresponding to its criterion.

To deal with the crisp input datasets, the membership function is constructed after consulting the expert's opinions, while for the data in categorical form, the membership values in [0,1] are directly assigned based on definition in Table 3. Then we can obtain all the performance scores (*PS*) in fuzzy decision matrix as

$$\left(PS\right)_{mxm} = \begin{array}{c} \\ A_1 \\ A_2 \\ \ldots \\ A_m \end{array} \overset{\begin{array}{cccc} C_1 & C_2 & \ldots\ldots & C_n \end{array}}{\begin{bmatrix} \mu_1\left(\tilde{x}_1\right) & \mu_1\left(\tilde{x}_2\right) & \ldots & \mu_1\left(\tilde{x}_n\right) \\ \mu_2\left(\tilde{x}_1\right) & \mu_2\left(\tilde{x}_2\right) & \ldots & \mu_2\left(\tilde{x}_n\right) \\ \ldots & \ldots & \ldots & \ldots \\ \mu_m\left(\tilde{x}_1\right) & \mu_m\left(\tilde{x}_2\right) & \ldots & \mu_m\left(\tilde{x}_n\right) \end{bmatrix}} \tag{7}$$

where A_n denotes possible alternatives; C_n denotes criterion with which alternative performances are measured; $\tilde{x}_{ij}$ denotes the performance score of alternative A_n with respect to criterion C_n, and $\mu_i\left(\tilde{x}_j\right) \in [0,1]$.

Step 3: Determine the power of *dilation* or *concentration* for each criterion and aggregate the DMs opinion denoted as

$$\tilde{D} = \begin{pmatrix} \mu_{11}^{(w_1)} & \mu_{12}^{(w_2)} & \ldots & \mu_{1n}^{(w_n)} \\ \mu_{21}^{(w_1)} & \mu_{22}^{(w_2)} & \ldots & \mu_{2n}^{(w_n)} \\ \ldots & \ldots & \ldots & \ldots \\ \mu_{m1}^{(w_1)} & \mu_{42}^{(w_2)} & \ldots & \mu_{mn}^{(w_4)} \end{pmatrix} \tag{8}$$

Step 4: The best alternative can be determined by maximising the minimum membership value over all the criteria using

$$\mu_{\tilde{D}}(x_i) = \max_i \left(\min_j \mu_{ij}^{w_j} \right) \tag{9}$$

Then, the ranking of all alternatives can be determined easily in descending order. In an attempt to explain the above procedures, we present in the next section the application for the proposed approach in a numerical example.

5. A Numerical Example

In this section, the example from Zamali *et al.* (2013) is adopted to demonstrate the proposed method. Every semester MDAB committee of UiTM Sabah receive more than 1000 applications from low income family candidates especially from the rural area across the state of Sabah, East of Malaysia. Since UiTM Sabah has faced financial constraint and limited space available to be offered, the committee makes an initial screening and short list for qualified candidates (i.e. A_i ; $i = 1,2,3,\ldots,n$) for Pre-Diploma (Commerce) programme. UiTM has three specific criteria which the candidates have to satisfy: i) C_1: parent gross monthly income (PI) must be less than RM3000, ii) C_2: obtain at least three credits (CR) in SPM results including *Bahasa Malaysia*, and iii) C_3: number of siblings (NS). Also the government of Malaysia has an exclusive criterion, that the candidates offered should be native (*Bumiputera*) and he/she must provide all the necessary documents (C_4) in the application. Thus, the committee is constructing the membership functions as given in Eqs. (4) – (6), respectively. For the document status criterion (C_4), the committee also decides to categorise the status of *Bumiputera* using four different scores (i.e. membership values) depending on the completeness of documents provided during the application submission (*see* Table 3).

However, for numerical example purposes, say five candidates have applied to enroll at UiTM Sabah. Here, we derive the scores for three criteria (C_1, C_2, and C3) from raw datasets in Table 4 using the three memberships function, respectively. Meanwhile, for the last criterion (C_4), we identify the document status based on the definition in Table 3 and summarise the results as in Table 4 (last row). Then, we obtain all the membership values as shown in Table 5.

Table 4: The raw datasets for four criteria

Candidates Criteria (C_i; $i = 1,2,3,4$)	A_1	A_2	A_3	A_4	A_5
C_1: Income (in RM)	1800	1000	700	2780	550
C_2: Number of credit obtained	3	5	4	3	5
C_3: Number of siblings	3	5	4	7	7
C_4: Document status	DS_4	DS_1	DS_2	DS_3	DS_4

Table 5: The membership values (i.e., the scores) derived from Table 4

Candidates	A_1	A_2	A_3	A_4	A_5
C_1: Income (RM)	0.4	0.67	0.77	0.07	0.82
C_2: Number of credit obtained	0.2	0.5	0.4	0.2	0.5
C_3: Number of siblings	0.5	0.75	0.75	1	1
C_4: Document status	1	0	0.3	0.7	1

Three DMs are involved and they make an assessment based on their expertise and experiences. The finalised evaluation for each group represents the mutual consensus between them as shown in Table 6. The three DMs are; i) Rector (D^1), ii) Deputy Rector (Academic Affairs) (D^2) and iii) MDAB Coordinator (D^3). Based on section 4.2, the computational procedure is given as follows:

Step 1: Decompose the problem (identify goal, criteria, and alternatives) and construct the hierarchical structure as shown in Fig. 1.

Step 2: Determine all the scores (membership values) for each criterion (C_i ; i = 1,2,3) based on the membership functions from Table 2, while for document status (DS) criteria (C_4), the membership values was directly obtained based on definition in Table 3. Then, calculate all the performance score and the results obtained are shown in the matrix below.

$$(PS)_{m\times n} = \begin{bmatrix} 0.40 & 0.20 & 0.50 & 1.0 \\ 0.67 & 0.5 & 0.75 & 0 \\ 0.77 & 0.40 & 0.75 & 0.30 \\ 0.07 & 0.20 & 1.0 & 0.70 \\ 0.82 & 0.50 & 1.0 & 1.0 \end{bmatrix}$$

Table 6: The important hedges for all criteria based on DMs judgement

Criteria	DMs D^1	D^2	D^3
C_1	*EI*	*EI*	*EI*
C_2	*I*	*VI*	*EI*
C_3	*VI*	*I*	*VI*
C_4	*EI*	*EI*	*EI*

Notes: EI~ Extremely Important; I ~ Important; VI~ Very Important;

Step 3: Aggregate the DMs opinions and determine the power of *dilation* or *concentration* for each criterion from Table 6.

Assuming all three DMs have an equal importance, the average aggregated power of *dilation* or *concentration* for the first criteria (C_1) can be calculated as $w_1 = (3 + 3 + 3)/3 = 3$. Similarly, the values of w_2, w_3, and w_4 for criterion C_i (i = 2, 3, 4) can be obtained as 2, 5/3, 3, respectively and the results are given by the following matrix:

$$\tilde{D} = \begin{bmatrix} 0.0640 & 0.0400 & 0.3143 & 1.0 \\ 0.3008 & 0.2500 & 0.6185 & 0 \\ 0.4565 & 0.1600 & 0.6185 & 0.0270 \\ 0.0003 & 0.0400 & 1.0 & 0.3430 \\ 0.5514 & 0.2500 & 1.0 & 1.0 \end{bmatrix}$$

Step 4: Determine the best candidates and ranked them by in descending order.

From Eq. (9), the minimum in each alternative can be obtained as A_1 = 0.0400, A_2 = 0, A_3 = 0.0270, A_4 = 0.0003 A_5 = 0.2500, respectively. Obviously, A_5 is the best choice followed by A_1, A_3, A_4, and the last choice is A_2 (*see* Table 7 in last column).

Table 7: Comparison of performance scores for both methods

Candidates	*Performance scores* (A_i ; *i* = 1, 2, 3, 4, 5)	*Ranking*	*Ranking in* Zamali *et al.* (2013)	*New ranking by proposed method*
A_1	0.20	3		
A_2	0.01	5		
A_3	0.40	2	$A_5 > A_3 > A_1 > A_4 > A_2$	$A_5 > A_1 > A_3 > A_4 > A_2$
A_4	0.07	4		
A_5	0.50	1		

Note: The symbol '>' means "prefer to" or "superior to"

For the sake of comparison, the intersection of fuzzy goal and constraints method is used to treat the same problem. The procedure and the detail analysis can be found in Zamali *et al.* (2013), and here we only present the final overall performance scores for each candidate as shown in Table 7. It is clear that by using this method, minor changes in the second and third ranking take place; A_1 is the third choice among five alternatives when compared to A_3 in our proposed method, while the rest of the ranking remain unchanged for both methods. Therefore, by using the proposed method, the ranking result is slightly different (in the case of second and third ranking) due to allowing DMs to assign the important weights verbally for each criterion using linguistic hedges. This weight elements in this particular case were totally ignored in our previous method (i.e., the intersection of fuzzy goal and constraints method), although this requirement is vital and highly significant in real decision-making environment.

6. Conclusion

In this paper we have proposed the AHP based on linguistic hedges for choosing the MDAB students. The result shows slightly different in terms of final ranking specifically for second and third alternatives. Previous work was done by Zamali *et al.* (2013) who introduced the intersection fuzzy goal and constraints method to choose the best *n*-MDAB students in selection process. The disadvantage of this method is that it did not represent the actual situation in the sense that the decision making process solely based on the candidates' attributes consideration which did not involve the DMs judgment. However, in this paper we overcome this disadvantage by allowing group DMs to assign the weights for each criterion based on their experiences and expertise. This is done by utilising the power of linguistic hedges, namely *concentration* or *dilation* to evaluate the level of each important criterion from their perspective. It is found that, the approach has given the significant impact of the final ranking and it is successful in dealing with the complexity and can derive more precise results. Moreover, the method also possesses intuition which considers the human rethinking-model in line with the nature of the human being to use linguistic expressions as an evaluation mechanism for tracking the criterion subjectivity. As a result, it facilitates the DMs to make a decision in a simple and systematic manner.

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Department of Mathematics
Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA (Sabah Branch)
Locked Bag 71
88997 Kota Kinabalu
Sabah, MALAYSIA
E-mail: zamalihj@sabah.uitm.edu.my[*]*, ungli720@sabah.uitm.edu.my, nasra040@sabah.uitm.edu.my, tammi023@sabah.uitm.edu.my*

[*]Corresponding author