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Opinion Based Fuzzy Measurement Model

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ABSTRACT

This paper proposes a fuzzy measurement model for decision-making which is fully based on respondents' opinion. The usage of fuzzy concept in determining the importance of criteria and performance ratings allows the measurement to consider the imprecise and vague human judgment. As respondents involved in the decision-making process may have different perspective, thus in this paper the linguistic terms represented by fuzzy numbers were developed based on respondents' opinion. The fuzzy measurement model consists of two phases which are the development of linguistic terms based on respondents' opinion and the performance measurement based on the developed fuzzy numbers. The applicability of the proposed fuzzy measurement model is demonstrated in a case study of quality award assessment of four departments in one higher institution in Malaysia. The proposed model considers the contribution of human judgment throughout the performance measurement process which is the rationale of implementing fuzzy concept.

Keywords: *Fuzzy measurement; fuzzy numbers; quality award; respondents' opinion.*

1. INTRODUCTION

Measuring the performance of alternatives is an important procedure for many applications such as approximate reasoning, decision-making, optimization, forecasting and control. However, to determine the best alternative is not an easy task as it involves human judgement which is vague, imprecise and uncertain. In decision-making, many studies has applied fuzzy concept which consider the existing of uncertainty in the performance measurement process. Wu [1] proposed a method for measuring the performance of alternatives based on data envelopment analysis and fuzzy preference relations. Moon *et al.* [2] developed a system for measuring the performance appraisal of military organization using fuzzy mean value concept and electronic nominal group techniques. Wang and Chen [3] presented a model for measuring the performance of high school teachers based on fuzzy number arithmetic operations.

In other studies, Yang and Hsieh [4] has applied Delphi fuzzy multiple criteria decision-making method in measuring the performance of project criteria of national quality award. Ramli *et al.* [5] has measured the quality of teaching performance with outliers' data by using fuzzy approach. Aydin *et al.* [6] has used fuzzy analytic hierarchy process in measuring the performance of firms for quality management excellence award. Da Silva [7] has employed the extended fuzzy TOPSIS from [8] to measure the performance of services in a health

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insurance company. Awasthi [9] has applied fuzzy TOPSIS and fuzzy simple aggregated weighting for measuring the performance quality of supplier under lack of quantitative information and multiple perspectives. Recently, Kumar *et al*. [10] has used fuzzy extended ELECTRE approach for measuring the performance quality of green suppliers.

However, in many fuzzy decision-making cases, the linguistic terms used are represented by fixed triangular or trapezoidal fuzzy numbers which were taken from the literature. Respondents involved in the decision-making process may have different perspective on the representation of fuzzy numbers for the linguistic terms [11]. According to [12], decision makers have the option to define their own range for the linguistic term to be used in the evaluation process. Similarly, Li and Kuo [13] stated that it is possible to construct fuzzy numbers according to decision makers. Thus, there is a need to consider the linguistic terms represented by fuzzy numbers based on respondents' opinion. Besides that, the linguistic terms developed based on respondents will portray the contribution of human judgment throughout the measurement process which is the rationale of implementing fuzzy concept.

This paper proposes a fuzzy measurement model for decision-making which is fully based on human judgment throughout the evaluation process. The applicability of the proposed fuzzy measurement model is demonstrated in a case study of quality award assessment of four departments in one higher institution in Malaysia.

This paper is organized as follows: Section 2 presents the basic concepts of fuzzy numbers and the ranking fuzzy numbers (RFNs) method by Wang and Lee [14]. The proposed fuzzy measurement model is presented in Section 3. In Section 4, the applicability of the proposed fuzzy measurement model is demonstrated in a case study of quality award and its results are given in detail. Finally, the conclusion is given in Section 5.

2. PRELIMINARIES

Fuzzy numbers are an important element in the research of fuzzy set theory. Fuzzy numbers can be defined in the forms of triangular, trapezoidal, bell-shaped and other appropriate shaped membership functions.

Definition: A fuzzy number A is a fuzzy set in the universe discourse $X = \Re$ with the membership function defined as,

$$f_A(x) = \begin{cases} \mu_A^L(x), a_1 \le x \le a_2 \\ 1 \quad , a_2 \le x \le a_3 \\ \mu_A^R(x)\; a_3 \le x \le a_4 \\ 0 \quad , otherwise \end{cases} \tag{1}$$

where μ_A^L and μ_A^R are the left and right membership functions of the fuzzy number A respectively.

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2.1 Triangular Fuzzy Numbers

In solving decision making in fuzzy environment, triangular fuzzy number is one of the most common types of fuzzy numbers used in practice [15]. A triangular fuzzy number denoted as $A=(a,b,d)$ has a membership function defined as,

$$\mu_{\bar{A}}(x)=\begin{cases}\dfrac{x-a}{b-a}, & a\le x\le b\\ \dfrac{d-x}{d-b}, & b\le x\le d\\ 0, & otherwise\end{cases}$$

2.2 Revised RFNs Method based on Area between Centroid and Original Points

The RFNs method based on area between centroid and original points was proposed by Chu and Tsao [16] with the centroid point $(x(A), y(A))$ defined as follows:

$$x(A)=\frac{\int_{a_1}^{a_2} x\mu_A^L(x)dx+\int_{a_2}^{a_3} xdx+\int_{a_3}^{a_4} x\mu_A^R(x)dx}{\int_{a_1}^{a_2} \mu_A^L(x)dx+\int_{a_2}^{a_3} dx+\int_{a_3}^{a_4} \mu_A^R(x)dx}\ and\ y(A)=\frac{\int_0^w yg_A^L(y)dy+\int_0^w yg_A^R(y)dy}{\int_0^w g_A^L(y)dy+\int_0^w g_A^R(y)dy} \quad (2)$$

where g_A^L and g_A^R are the inverse function of f_A^L and f_A^R respectively.

Wang and Lee [14] found that the method produces counterintuitive results and degrades the importance value of *x*. To improve [16], they [14] presented a revised method for RFNs *A* and *B* based on the following situations:

(i) If $x(A)\succ x(B)$, then $A\succ B$.
(ii) If $x(A)\prec x(B)$, then $A\prec B$.
(iii) If $x(A)=x(B)$, then
 If $y(A)\succ y(B)$, then $A\succ B$
 else if $y(A)\prec y(B)$, then $A\prec B$.
 else $y(A)=y(B)$, then $A\approx B$.

3. OPINION BASED FUZZY MEASUREMENT MODEL

The proposed opinion based fuzzy measurement model consists of two phases with phase one is the development of linguistic terms in the form of triangular fuzzy numbers based on respondents' opinion. Phase two is the evaluation process for importance level of criterion and ratings on alternatives.

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3.1 Development of Linguistic Terms based on Opinion

The respondents have to determine the range of scaling for each linguistic term used, where the range for the linguistic terms must be between 0 to 100. The lower and upper values must be logically related to its linguistic term.

For k respondents, the lower limit, modal and upper limit of the respect linguistic terms denoted as a, b and d respectively, are given as

$$a = \min(L_1, L_2, L_3, \ldots, L_k),$$

$$d = \max(U_1, U_2, U_3, \ldots, U_k),$$

$$b = \frac{\sum_{i=1}^{k} M_i}{k} \tag{3}$$

where
L_i is the lower limit of range of the respect linguistic term for i-th respondent,
U_i is the upper limit of range of the respect linguistic term for i-th respondent,

$M_i = \frac{1}{2}(L_I + U_i)$ of the respected linguistic term for i-th respondent, for i = 1, 2, …, k.

3.2 Evaluation for Importance and Performance Level

Decision makers evaluate the importance level of each criterion and the performance of each alternative. The evaluation process uses fuzzy linguistic terms throughout the process. The evaluation procedures are presented as follows:

Step 1: Determine the fuzzy weight of each criterion. For K decision maker, the fuzzy weight $\tilde{w}_i$ of each criterion is defined as

$$\tilde{w}_i = \frac{\sum_{k=1}^{K} \tilde{w}_i^k}{K} \tag{4}$$

where $\tilde{w}_i^k$ is the importance weight of criterion X_i by the k-th decision maker.

Step 2: Determine the fuzzy grade of each alternative with respect to each sub-criterion. For K decision maker, the fuzzy grade $\tilde{g}_{ij,m}$ of alternative m with respect to sub-criterion X_{ij} is defined as

$$\tilde{g}_{ij,m} = \frac{\sum_{k=1}^{K} \tilde{x}_{ij,m}^k}{K} \tag{5}$$

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where $\tilde{x}_{ij,m}^{k}$ is rating of sub-criterion X_{ij} for alternative *m* by the *k*-th decision maker.

Step 3: Determine the fuzzy grade of each alternative with respect to each criterion. For p sub criteria of criterion X_i, the fuzzy grade $\tilde{g}_{mi}$ of alternative *m* with respect to criterion X_i is defined as

$$\tilde{g}_{mi} = \frac{\sum_{j=1}^{p} \tilde{g}_{ij,m}}{p} \tag{6}$$

Step 4: Build the fuzzy grade matrix $\tilde{G}$ defined as

$$\tilde{G} = \begin{matrix} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{matrix} \begin{bmatrix} X_1 & X_2 & \cdots & X_k \\ \tilde{g}_{11} & \tilde{g}_{12} & \cdots & \tilde{g}_{1k} \\ \tilde{g}_{21} & \tilde{g}_{22} & \cdots & \tilde{g}_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{g}_{n1} & \tilde{g}_{n2} & \cdots & \tilde{g}_{nk} \end{bmatrix} \tag{7}$$

where $\tilde{g}_{mi}$ denotes the fuzzy grade of the *m*-th alternative A_m with respect to the *i*-th criterion X_i, $1 \le m \le n, 1 \le i \le k$, *n* denotes the number of alternatives and *k* denotes the number of criteria.

Step 5: Calculate the total fuzzy grade vector $\tilde{R}$ with

$$\tilde{R} = \tilde{G} \otimes \tilde{W} = \begin{bmatrix} \tilde{g}_{11} & \tilde{g}_{12} & \cdots & \tilde{g}_{1k} \\ \tilde{g}_{21} & \tilde{g}_{22} & \cdots & \tilde{g}_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{g}_{n1} & \tilde{g}_{n2} & \cdots & \tilde{g}_{nk} \end{bmatrix} \otimes \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_k \end{bmatrix} = \begin{bmatrix} \tilde{R}_1 \\ \tilde{R}_2 \\ \vdots \\ \tilde{R}_n \end{bmatrix} \tag{8}$$

where $\tilde{W} = [\tilde{w}_1 \quad \tilde{w}_2 \quad \ldots \quad w_k]^T$, $\tilde{w}_i$ is the fuzzy weight of criterion X_i and $1 \le i \le k$, $\tilde{R}_m$ denotes the total fuzzy grade of the *m*-th alternative A_m and $1 \le m \le n$.

Step 6: Rank the total fuzzy grade $\tilde{R}_m$ using the revised centroid ranking method from [14].

4. A CASE STUDY

The applicability of the proposed fuzzy measurement model is demonstrated in a case study of quality award assessment in a government higher institution in Malaysia. The management review report (MRR) of four departments (namely as A_1, A_2, A_3 and A_4) in the higher institution will be evaluated. The institution considered eight criteria for the quality award which are (i) leadership X_1 (ii) strategic planning X_2 (iii) customer focus X_3 (iv)

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measurement, analysis and knowledge X_4 (v) workforce focus X_5 (vi) process management X_6 (vii) results X_7 and, (vii) innovation X_8. Each of X_1, X_2, X_3, X_4, X_6 and X_8 are divided into two sub-criteria, while X_5 and X_7 are divided into three and four sub-criteria respectively. Two sets of questionnaires were constructed where set one is the questionnaire for determining the scale for linguistic terms. Seven respondents whom are the head of quality in the institution filled the questionnaire. The second set of questionnaires is to determine the importance and performance levels of MRR for each department. Three appointed decision makers involved in the evaluation process.

4.1 Questionnaires

Two sets of questionnaires were constructed where set one is the questionnaire for determining the scale for linguistic terms. Seven respondents whom are the head of quality in the institution filled the questionnaire. The second set of questionnaire is to determine the importance and performance levels of MRR for each department. Three appointed decision makers involved in the evaluation process.

4.2 Development of Linguistic Terms

The scaling of importance level and performance given by the seven respondents are shown in Table 1 and 2 respectively.

Table 1: Respondents' Opinions for Importance Level

Respondent	Very Low (VL)	Low (L)	Medium Low (ML)	Medium (M)	Medium High (MH)	High (H)	Very High (VH)
1	0-15	15-30	30-46	46-55	55-70	70-85	85-100
2	0-15	15-20	20-40	40-60	60-70	70-85	85-100
3	0-30	30-50	50-60	60-70	70-80	80-90	90-100
4	0-10	10-15	15-30	30-50	50-70	70-90	90-100
5	0-10	10-30	30-50	50-70	70-80	80-90	90-100
6	0-10	10-30	30-50	50-70	70-80	80-90	90-100
7	0-10	10-30	30-50	50-70	70-80	80-90	90-100

Table 2: Respondents' Opinions for Performance Level

Respondent	Very Poor (VP)	Poor (P)	Medium Poor (MP)	Fair (F)	Medium Good (MG)	Good (G)	Very Good (VG)
1	0-15	15-30	30-46	46-55	55-70	70-85	85-100
2	0-10	10-18	18-35	35-65	65-80	80-90	90-100
3	0-20	20-40	40-50	50-60	60-75	75-85	85-100
4	0-10	10-15	15-30	30-50	50-70	70-90	90-100
5	0-10	10-30	30-50	50-70	70-80	80-90	90-100
6	0-10	10-30	30-50	50-70	70-80	80-90	90-100
7	0-10	10-30	30-50	50-70	70-80	80-90	90-100

Table 3 shows the calculation for triangular fuzzy number (TFN) of Very Poor (VP) based on Eq. (3). respectively.

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Table 3: Calculation for TFN Very Poor

Respondent, i	L_i	U_i	$M_i = \frac{1}{2}(L_i + U_i)$
1	0	15	7.5
2	0	10	5
3	0	20	10
4	0	10	5
5	0	10	5
6	0	10	5
7	0	10	5
	$\min(L_i)$	$\max(U_i)$	$average(M_i)$
TFN	0	20	6.071

Thus, the linguistic term for Very Poor is (0, 6.071, 20). By using similar technique, the linguistic term for importance and performance levels based on respondents' opinion are given as in Tables 4 and 5 respectively.

Table 4: Linguistic Terms for Importance Level based on Respondents' Opinion

Linguistic term	TFN
Very Low (VL)	(0, 7.143, 30)
Low (L)	(10, 21.786, 50)
Medium Low (ML)	(15, 37.929, 60)
Medium (M)	(30, 55.071, 70)
Medium High (MH)	(50, 69.643, 80)
High (H)	(70, 82.143, 90)
Very High (VH)	(85, 94.286, 100)

Table 5: Linguistic Terms for the Performance Level based on Respondents' Opinion

Linguistic term	TFN
Very Poor (VP)	(0, 6.071, 20)
Poor (P)	(10, 19.857, 40)
Medium Poor (MP)	(15, 36, 50)
Fair (F)	(30, 53.643, 70)
Medium Good (MG)	(50, 69.643, 80)
Good (G)	(70, 82.5, 90)
Very Good (VG)	(85, 94.286, 100)

Based on Tables 4 and 5, the spread of TFN is not symmetric where the right and left spreads of the TFN are not equal. However, in most of the fixed TFN used in literature, the spread is symmetric. This shows that respondents' opinion affected the representation of TFNs for linguistic term where the spread may not be symmetric.

4.3 Evaluation of Importance and Performance Level

Three decision makers D_1, D_2 and D_3 evaluate the importance level of each criterion X_1, X_2, X_3, X_4, X_6 and X_8. The evaluation for importance level for criterion X_1 is given in Table 6.

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Table 6: The Evaluation for Importance Level of Criterion X_i

Criteria	Evaluator D_1	Evaluator D_2	Evaluator D_3
X_1	MH	ML	H

Three decision makers D_1, D_2 and D_3 evaluate the performance of alternative for each sub-criterion X_{ij}. Table 7 shows the ratings for department A_3 for sub-criteria X_{11} and X_{12}.

Table 7: The Performance Ratings for Sub-criteria X_{11} and X_{12} for Department A_3

Criteria	Sub-criteria	Evaluator D_1	Evaluator D_2	Evaluator D_3
X_1	X_{11}	MP	MG	F
	X_{12}	MP	MG	F

Based on Table 6 and Eq. (4), the fuzzy weight X_1 for the importance level is given as follows

$$\tilde{w}_1 = \frac{(50,69.643,80)+(15,37.929,60)+(70,82.143,90)}{3} = (45,63.238,76.667)$$

The fuzzy weighted vector for eight criteria according to the importance level is represented as follows

$$\tilde{W} = \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \tilde{w}_3 \\ \tilde{w}_4 \\ \tilde{w}_5 \\ \tilde{w}_6 \\ \tilde{w}_7 \\ \tilde{w}_8 \end{bmatrix} = \begin{bmatrix} (45, 63.238, 76.667) \\ (38.333, 59.072, 73.333) \\ (25, 43.119, 63.333) \\ (38.333, 58.381, 73.333) \\ (25, 43.119, 63.333) \\ (18.333, 38.262, 60) \\ (75, 86.191, 93.333) \\ (25, 43.119, 63.333) \end{bmatrix} \quad (9)$$

Based on the fuzzy weight $\tilde{w}_i$ in Eq. (9) and the centroid ranking formulae in Eq. (2), the $x(\tilde{w}_i)$ and $y(\tilde{w}_i)$ are given in Table 8.

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Table 8: $x(\tilde{w}_i)$ and $y(\tilde{w}_i)$

Fuzzy number, $\tilde{w}_i$	$x(\tilde{w}_i)$	$y(\tilde{w}_i)$
$\tilde{w}_1$	61.635	0.503
$\tilde{w}_2$	56.913	0.505
$\tilde{w}_3$	43.817	0.498
$\tilde{w}_4$	56.683	0.504
$\tilde{w}_5$	43.817	0.498
$\tilde{w}_6$	38.865	0.498
$\tilde{w}_7$	84.841	0.502
$\tilde{w}_8$	43.817	0.498

Based on decision makers' opinions for performance level, the fuzzy grade $\tilde{g}_{ij,m}$ can be determined by Eq. (5). Based on Table 7 and Eq. (5), the fuzzy grade $\tilde{g}_{12,3}$ of department A_3 with respect to sub-criterion X_{12} is shown as follows:

$$\tilde{g}_{12,3} = \frac{[(15, 36, 50) + (50, 69.643, 80) + (30, 53.643, 70)]}{3} = (31.667, 53.095, 66.667).$$

The fuzzy grades $\tilde{g}_{ij,m}$ of each department A_m with respect to each sub-criterion X_{ij} are presented as in Table 9.

Table 9: The Fuzzy Grade of each Department with respect to each Sub-criterion

Criteria	Sub-criteria	Department A_1	Department A_2	Department A_3	Department A_4
X_1	X_{11}	(43.333,64.310,76.667)	(63.333,78.214,86.667)	(31.667,53.095,66.667)	(36.667,58.976,73.333)
	X_{12}	(50,68.595,80)	(56.667,73.929,83.333)	(31.667,53.095,66.667)	(36.667,58.976,73.333)
X_2	X_{21}	(63.333,78.214,86.667)	(56.667,73.929,83.333)	(31.667,53.095, 66.667)	(50,68.595,80)
	X_{22}	(50,69.643,80)	(56.667,73.929,83.333)	(36.667,58.976, 73.333)	(38.333,58.429, 70)
X_3	X_{31}	(43.333,64.310,76.667)	(50,68.595,80)	(25,47.762, 63.333)	(36.667,58.976,73.333)
	X_{32}	(50,69.643,80)	(56.667,73.929,83.333)	(23.333,42.381, 60)	(31.667,53.095,66.667)
X_4	X_{41}	(36.667,58.976,73.333)	(43.333,64.310,76.667)	(25,47.762,63.333)	(31.667,53.095,66.667)
	X_{42}	(30,53.643,70)	(36.667,58.976,73.333)	(20,41.881,56.667)	(25,47.762, 63.333)
X_5	X_{51}	(36.667,58.976,73.333)	(50,68.595,80)	(25,47.762,63.333)	(30,53.643,70)
	X_{52}	(50,68.595,80)	(56.667,73.929,83.333)	(20,41.881,56.667)	(30,53.643,70)
	X_{53}	(43.333,64.310,76	(50,69.643,80)	(20,41.881,56	(30,53.643,70)

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		.667)		.667)	
X_6	X_{61}	(63.333,78.214,86.667)	(56.667,73.929,83.333)	(25,47.762,63.333)	(50,68.595,80)
	X_{62}	(50,69.643,80)	(56.667,73.929,83.333)	(20,41.881,56.667)	(43.333,64.310,76.667)
X_7	X_{71}	(36.667,58.976,73.333)	(36.667,58.976,73.333)	(13.333,30.619,46.667)	(36.667,58.976,73.333)
	X_{72}	(30,53.643,70)	(43.333,64.310,76.667)	(10,26.024,40)	(30,53.643,70)
	X_{73}	(30,53.643,70)	(36.667,58.976,73.333)	(10,26.024,40)	(31.667,53.095,66.667)
	X_{74}	(36.667,58.976,73.333)	(43.333,64.310,76.667)	(10,26.024,40)	(31.667,53.095,66.667)
X_8	X_{81}	(31.667,53.095,66.667)	(36.667,58.976,73.333)	(18.333,36.5,53.333)	(31.667,53.095,66.667)
	X_{82}	(36.667,58.976,73.333)	(36.667,58.976,73.333)	(18.333,36.5,53.333)	(36.667,58.976,73.333)

Based on Table 9, the fuzzy grade $\tilde{g}_{mi}$ of alternative *m* with respect to criterion X_i can be determined by Eq. (6). For example, the calculation for fuzzy grade $\tilde{g}_{17}$ of campus A_1 with respect to criterion X_7 is shown as follows:

$$\tilde{g}_{17} = \frac{(36.667,\ 58.976,\ 73.333) + (30,\ 53.643,\ 70) + (30,\ 53.643,\ 70) + (36.667,\ 58.976,\ 73.333)}{4}$$
$$= (33.334,\ 56.310,\ 71.667)$$

In similar manner, we can obtain $\tilde{g}_{mi}$ for $\forall i = 1,2,\ldots 8$ and $\forall m = 1,2,3,4.$

Further, the fuzzy grade matrix G as defined in Eq. (7) is presented as follows:

$$\tilde{G} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array}\left[\begin{array}{cccccccc} X_1 & X_2 & X_3 & X_4 & X_5 & X_6 & X_7 & X_8 \\ (46.667,66.453,78.334) & (56.667,73.929,83.334) & (46.667,66.977,78.334) & (33.334,56.310,71.667) & (43.333,63.96,76.667) & (56.667,73.929,83.334) & (33.334,56.31,71.667) & (34.167,56.036,70) \\ (60,76.072,85) & (56.667,73.929,83.333) & (53.334,71.262,81.667) & (40,61.643,75) & (52.222,70.722,81.111) & (56.667,73.929,83.333) & (40,61.643,75) & (36.667,58.976,73.333) \\ (31.667,53.095,66.667) & (34.167,56.036,70) & (24.167,45.072,61.667) & (22.5,44.822,60) & (21.667,43.841,58.889) & (22.5,44.822,60) & (10.833,27.173,41.667) & (18.333,36.5,53.333) \\ (36.667,58.976,73.333) & (44.167,63.512,75) & (34.167,56.036,70) & (28.334,50.429,65) & (30,53.643,70) & (46.667,66.453,78.334) & (32.5,54.702,69.167) & (34.167,56.036,70) \end{array}\right] \quad (10)$$

Based on the fuzzy weighted vector $\tilde{W}$ in Eq. (8), (9) and (10) the total fuzzy grade vector $\tilde{R}$ can be determined. The calculation for total fuzzy grade $\tilde{R}_1$ of campus A_1 is shown as follows:

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$$\tilde{R}_1 = (\tilde{g}_{11} \times \tilde{w}_1) + (\tilde{g}_{12} \times \tilde{w}_2) + (\tilde{g}_{13} \times \tilde{w}_3) + (\tilde{g}_{14} \times \tilde{w}_4) + (\tilde{g}_{15} \times \tilde{w}_5) + (\tilde{g}_{16} \times \tilde{w}_6) + (\tilde{g}_{17} \times \tilde{w}_7) + (\tilde{g}_{18} \times \tilde{w}_8)$$

$$= [(46.667,66.453,78.334) \times (45,63.238,76.667)] + [(56.667,73.929,83.334) \times (38.333,59.072,73.333)] +$$
$$[(46.667,66.977,78.334) \times (25,43.119,63.333)] + [(33.334,56.31,71.667) \times (38.333,58.381,73.333)] +$$
$$[(43.333,63.96,76.667) \times (25,43.119,63.333)] + [(56.667,73.929,83.334) \times (18.333,38.262,60)] +$$
$$[(33.334,56.31,71.667) \times (75,86.191,93.333)] + [(34.167,56.036,70) \times (25,43.119,63.333)]$$
$$= (12193.124, 27601.098, 43311.246)$$

In the same way, we can get the total fuzzy grade vector $\tilde{R}$ as follow.

$$\tilde{R} = \begin{bmatrix} \tilde{R}_1 \\ \tilde{R}_2 \\ \tilde{R}_3 \\ \tilde{R}_4 \end{bmatrix} = \begin{bmatrix} (12193.124, 27601.098, 43311.246) \\ (13999.987, 29583.492, 45081.302) \\ (6426.374, 18749.264, 33146.267) \\ (10180.592, 24828.310, 40344.375) \end{bmatrix} \quad (11)$$

Based on Eq. (2) and (11), the ranking order of $\tilde{R}_m$ is shown in Table 10. Based on Table 8 and the ranking index by [19], the ranking order is $\tilde{w}_6 \prec \tilde{w}_8 \approx \tilde{w}_5 \approx \tilde{w}_3 \prec \tilde{w}_4 \prec \tilde{w}_2 \prec \tilde{w}_1 \prec \tilde{w}_7$. This shows that the three decision makers ranked criterion X_7 (results) as the most important, followed by X_1 (leadership), X_2 (strategic planning) and X_4 (measurement, analysis and knowledge). Criteria X_3 (customer focus), X_5 (workforce) and X_8 (innovations) have equal importance and X_6 (process management) is the least important. Table 10 shows the comparison of weight for each criterion with the previous studies.

Table 10: The Ranking Order of $\tilde{R}_1$, $\tilde{R}_2$, $\tilde{R}_3$ and $\tilde{R}_4$

Fuzzy number, $\tilde{R}_m$	$x(\tilde{R}_i)$	$y(\tilde{R}_i)$	Ranking order
$\tilde{R}_1$	27701.823	0.499	2
$\tilde{R}_2$	29554.927	0.500	1
$\tilde{R}_3$	19440.635	0.499	4
$\tilde{R}_4$	25117.759	0.498	3
Total ordering	$\tilde{R}_2 \succ \tilde{R}_1 \succ \tilde{R}_4 \succ \tilde{R}_3$		

Table 11: Weight Comparison with Previous Studies

Criteria	Ranking				
	[17]	[18]	[19]	[20]	Proposed model
Leadership, X_1	2	7	2	2	5
Strategic planning, X_2	6	8	5	4	4
Customer focus, X_3	3	3	4	4	2
Measurement, analysis and knowledge, X_4	5	5	8	3	3
Workforce, X_5	4	4	7	4	2
Process management, X_6	7	6	6	4	1
Results, X_7	1	2	1	1	6
Innovations, X_8	-	1	3	-	2

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Table 11 indicates that process management X_6, was pinpointed by decision makers as the leading factor affecting the quality award measurement process and followed by customer focus X_3, workforce X_5 and innovations X_8. The leadership X_1 and results X_7 were identified as the least importance to the quality award assessment. The relatively higher and lower importance of criterion X_8 (innovations) and criterion X_1 (leadership) were also consistent with [18]. However, the lower contribution of leadership X_1 and results X_7 are found contradicting with [20], [17] and [19]. The most crucial factor process management X_6 is also found contradicting with [17].

Based on Eq. (10), the ranking order for criteria X_1 (leadership), X_3 (customer focus), X_4 (measurement, analysis and knowledge), X_5 (workforce) and X_7 (results) is $A_2 \succ A_1 \succ A_4 \succ A_3$. For criteria X_2 (strategic planning) and X_6 (process management), the ranking is $A_2 \approx A_1 \succ A_4 \succ A_3$ while for criterion X_8 (innovation) the ranking is $A_2 \succ A_1 \approx A_4 \succ A_3$. This shows that for all criteria, department A_2 is ranked as the best while department A_3 is ranked as the worst. Based on Table 9, the final ranking result is $A_2 \succ A_1 \succ A_4 \succ A_3$. This means that department A_2 is ranked as the best, followed by departments A_1, A_4 and A_3. The final ranking result is consistent with the importance level where for all criteria, department A_2 is ranked as the best while department A_3 is ranked as the worst. However, in [4], the best selection project has the best criteria in leadership X_1 and customer focus X_3. While the lowest ranked project has the lowest in criteria, workforce X_5 and results X_7.

5. CONCLUSSION

This paper proposes a fully human judgment measurement model for fuzzy decision-making process. The measurement process starts with the development of linguistic terms represented by TFNs based on respondents' opinion. The spread of TFNs obtained is not symmetric compared to most of the fixed TFNs used in literature [5], [21]. This indicates that the expression of linguistic terms in TFNs form is affected by respondents' opinion. The proposed method also considers both the importance level of each criterion and the performance level of each alternative based on human judgment throughout the process. The proposed fuzzy measurement model considers the contribution of human judgment throughout the evaluation which is the rationale of implementing fuzzy concept. This proposed performance measurement model can be applied for other applications which focus on total decision makers' expectation and need.

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