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Evaluating Students Assessment Group Project Using Fuzzy Analytic Hierarchy Process (FAHP)

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Abstract: In education, evaluation plays a major role in determining performance. Artificial intelligence systems have become popular in recent years to understand the process of human thinking and to move it to virtual environments. Evaluating a student's project can be effective in improving student performance. By combining qualitative and quantitative factors, fuzzy logic is used to express human thinking in mathematical concepts. It has become one of the most preferred methods in finding a solution to decision-making problems. The fuzzy Analytic Hierarchy Process (FAHP) is one of the multi-criteria decision-making (MCDM) methods based on fuzzy logic. In this case, FAHP has been proposed for evaluating students' group project assessments by determining the main criteria and sub-criteria used in the evaluation system. Three projects were selected based on four main criteria and 16 sub-criteria. A questionnaire was constructed based on the selected criteria. Three experts were requested to answer the questionnaire. The pairwise comparison was developed based on the opinion of the experts. Later, the main criteria and sub-criteria were formed in a mathematical number using a linguistic variable in a triangular fuzzy number (TFN). Ranking was formed from the result of every project. The result is compared by using a manual system and FAHP. According to the findings of this study, Alternative 3 has the highest weight compared to the others and similar to the manual rubric system.

Keywords: Fuzzy Analytic Hierarchy Process; manual system; multi-criteria decision-making; student assessment; triangular fuzzy number

1 Introduction

Students often wonder how lecturers grade their projects and what criteria are used. Sometimes, manual grading can be unfair, affecting their overall marks. Lecturers also struggle to fairly assess each student's contribution in group work. To solve this, the study used the FAHP method, a well-known tool for making decisions based on multiple criteria. This method helps set clear weights for each grading factor and ranks the projects fairly. The results aim to help both lecturers and students better understand the evaluation process.

Evaluating students' projects involves some certainties and subjectivity like other evaluations. For students' projects, lecturers mostly will give the details of the projects together with the rubric. Students follow the rubric as they complete all the criteria in finishing their projects [1]. The most significant criteria were content, design, technical, and presentation. Evaluation will be based on students' ability to apply knowledge and creativity in completing the criteria. Grading systems must be fair and accurate to reflect students' abilities and potential. The method of evaluating students' projects that has been suggested provides multiple test formats, allows for self-assessment, and changes the weighing scale. They must have more information to transfer the skills that suit a chosen problem.

Fuzzy logic is one of the ways that translate human behavior and express it in mathematical concepts by Cebi and Karal [1]. According to them, decision-making is a process which involves selecting the most suitable alternative according to the criteria that one faces with existing alternatives. According to Bai and Chen [2], decision-making is the toughest process because of its uncertainty and subjectivity to decision-makers.

The AHP, proposed by Saaty in 1980, utilizes pair-wise comparisons of weights to measure order, rank, and evaluate decision-making [3]. The FAHP was developed from MCDM which refers to significant decision-making involving multiple and conflicting criteria [4]. MCDM included quantitative and qualitative criteria. Since the 1960s, Roy [5] stated that MCDM has been an active area of study, producing numerous theoretical and applied articles and books. In cases where there are more than one opposing criterion, MCDM is a general term for all approaches that exist to help individuals make choices according to their interests [6].

According to Putra [7], the AHP is not only focusing on the human logic of thinking, but it is also focusing on evaluation criteria. The AHP is a method of decision support built to complete a problem by breaking down, grouping, and then organizing the information hierarchy structure. The FAHP method is similar to the AHP method but was developed with fuzzy logic theory. The mixing effect of the method of fuzzy set theory and analytical hierarchy provides FAHP with a more powerful multi-criteria decision-making methodology by Iftikhar and Siddiqui [8]. The FAHP process incorporates the decision-maker's uncertainty by applying a range of values.

In FAHP, the linguistic variables were used in performing pairwise comparison of both criteria and the alternatives represented by triangular numbers [9]. Linguistic variables are used to describe human feelings, emotions, and decisions [10]. In the realm of the humanistic system, the main applications lie in the fields of artificial intelligence, linguistics, human decision-making, pattern recognition, psychology, and many more [11]. So, linguistic variables are used to express an examiner's feelings in evaluating student projects based on the criteria given.

Although AHP can handle both quantitative and qualitative data, it cannot handle the inaccuracy, complexities, fuzziness, and vagueness of decision-makers [4]. An effective way of explaining uncertainty in the decision-making process is using fuzzy logic [12]. Based on [4], human uncertainties can be modeled by integrating fuzzy logic with a pair-wise comparison where this MCDM approach enables a more detailed description of the decision-making process.

There have been many studies using the fuzzy multicriteria decision-making method in different fields [13]. For some implementations, each multicriteria decision-making process has its privileges, control, and vulnerability [14]. According to Tang and Lin [15], in their research on the application of fuzzy analytic hierarchy process on lead-free equipment selection decision, it was found that FAHP has the potential to benefit the manufacturing industry by minimizing any negative effect of being forced to invest in a lead-free equipment system by new regulations.

Another research paper is about applying FAHP to evaluate and select a product of notebook computers [16]. There is also a research that uses FAHP to develop a selection score model [17]. This research used TFN in developing pair-wise comparison matrices and expert opinions were averaged to establish Fuzzy Evaluation Matrix. In this study, it shows that the fuzzy and non-fuzzy methods did not give any big impacts in evaluating student scores by making a comparison between AHP and FAHP. Other research were done regarding constructing a fuzzy AHP and fuzzy TOPSIS model to evaluate different notebook computer ODM companies [18]. This research is to generate a final evaluation on priority ranking for proposed notebook computer models using factors such as manufacturing capability, human resource capability, innovation capability, and so on.

2 Methodology

This study consists of ten steps as shown in Figure 1 below.

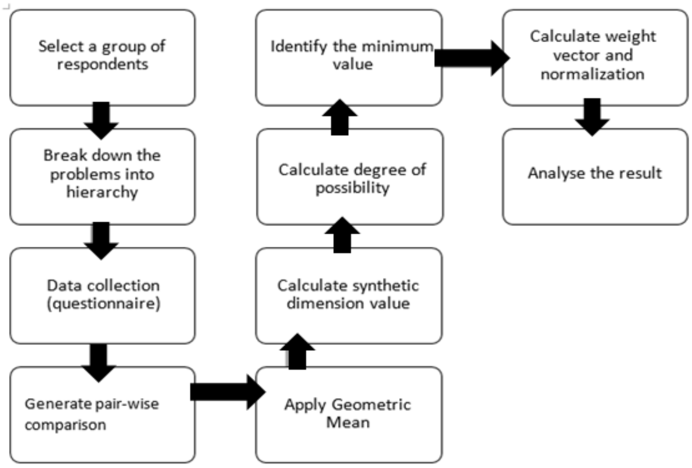

Figure 1: The Flowchart of FAHP Method

Step 1: Select a group of respondents
For the first step, experts were chosen as respondents. Opinion and knowledge from experts will be transfered into the Triangular Fuzzy Number.

Step 2: Break down the problems into hierarchy
The hierarchical structure will be designed based on the selected criteria, sub-criteria and project. The criteria and sub-criteria were based on [1]. These criteria and sub-criteria were verified by lecturers to ensure the validity of the criteria and sub-criteria.

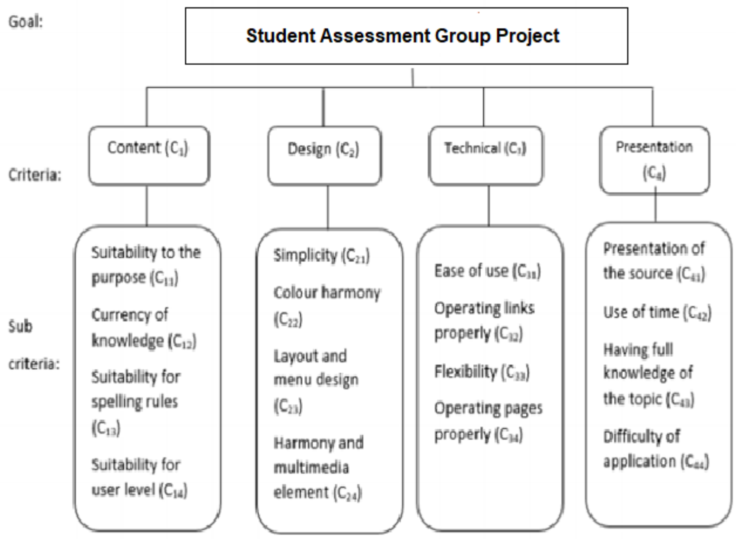

Figure 2: Heirarchical Structure

Step 3: Data Collection (Questionnaire)
The process of collecting data for this study is by using a questionnaire. The questionnaire was developed based on the criteria and sub-criteria. A questionnaire regarding the criteria and sub-criteria was answered by experts.

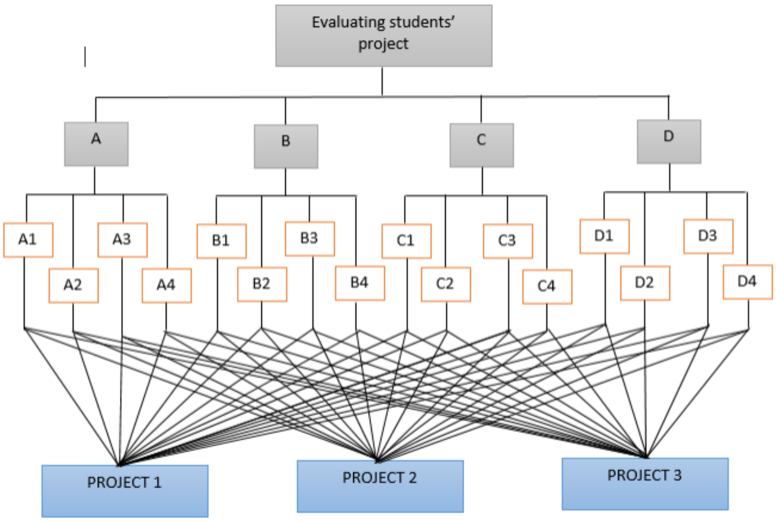

Figure 3: Questionnaire Hierarchical Structure

Step 4: Generate pair-wise comparison

According to [1], the TFN for linguistic variables is distinct and prepared by Erümit which is shown in Table 1. In this case, there were five linguistic variables used for comparing students' project evaluation which were Absolutely Important, Very Strongly Important, Strongly Important, Weakly Important and Equally Important.

Table 1: The triangular fuzzy number (TFN) equivalent of linguistic variable used in the evaluation

Linguistic Variable	Triangular Fuzzy Number, TFN	Reversed of TFN
Equally Important, E.I.	(1,1,1)	(1,1,1)
Weakly Important, W.I.	(0.5,1.25,2)	(0.5,0.8,2)
Strongly Important, S.I.	(1.5,2.25,3)	(0.33,0.44,0.66)
Very Strong Important, V.I.	(2.5,3.25,4)	(0.25,0.307,0.4)
Absolutely Important, A.I.	(3.5,4.25,5)	(0.2,0.235,0.285)

Step 5: Apply Geometric Mean

In this study, geometric mean $\tilde{d}_{ij}^{k}$ developed by [19] was used to aggregate experts' opinion. The geometric mean was calculated using the equation below.

$$\tilde{d}_{ij}^{k} = \frac{\sum_{K=1}^{k} \tilde{d}_{ij}^{k}}{k} \qquad (1)$$

where $\tilde{d}_{ij}^{k}$ indicates the k^{th} decision maker's preferences of i^{th} criterion over j^{th} criterion.

Step 6: Calculating synthetic dimension value, S_i

In this part, the synthetic dimension value was calculated as follows:
$M_{gi}^{1}, M_{gi}^{2}, M_{gi}^{3}, \ldots, M_{gi}^{m}$ where $g_i\,(i = 1,2,3,\ldots,n)$ is the goal set and all the $(j = 1,2,3,\ldots,m)$ are triangular fuzzy numbers (TFNs). Extended analysis method was developed by [20]. $\sum_{j=1}^{m} M_{gi}^{j}$ was obtained as in equation (2):

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \qquad (2)$$

New set will be obtained which is (l,m,u) that will be used in order to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ by performing fuzzy addition operation of $M_{gi}^{j}\left(j=1,2,3,...,m\right)$ such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_j, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_j\right) \tag{3}$$

And then compute inverse of the equation (4),

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{4}$$

The fuzzy synthetic extend value S_i with respect to the i_{th} criterion is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \tag{5}$$

Step 7: Calculate degree of possibility

The degree of possibility was calculated as follows:

Two triangular numbers $M_1=\left(l_1,m_1,u_1\right)$, $M_2=\left(l_2,m_2,u_2\right)$ and degree of possibility of equation is given by

$$M_2 \geq M_1$$

$$V\left(M_2 M_1\right) = \sup_y \geq x\left[\min\left(\mu M_1\left(x\right), \mu M_2\left(y\right)\right)\right]$$

This equation depends on the assumption of constructing a set to choose the strongest from the weak fuzzy correlation of μM_1 and μM_2. It is denoted that *d* is the highest intersection point of μM_1 and μM_2.

$$V\left(M_2 \geq M_1\right) = \begin{cases} 1 & \text{if } m_2 \geq m_1 \\ 0 & \text{if } l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{\left(m_2 - u_2\right) - \left(m_1 - l_1\right)} & \text{otherwise} \end{cases} \tag{6}$$

Step 8: Identify the minimum value

The minimum value is defined from the degree of possibility obtained from the last step and denoted by $d'\left(A_i\right)$.

Let $M_i\left(i=1,2,3,...,k\right)$ and

$$\begin{aligned} V\left(M \geq M_1, M_2, ..., M_k\right) &= V\left[\left(M \geq M_1\right), \left(M \geq M_2\right), ...\left(M \geq M_k\right)\right] \\ &= \min V\left(M \geq M_i\right);\ i=1,2,3,...,k;\ k=1,2,3,..,k; k \neq i \end{aligned} \tag{7}$$

Step 9: Calculate weight vector and normalization

Assuming $d'\left(A_i\right)$ = minimum value $V\left(S_i \geq S_k\right)$,

then

$$W' = \left(d'\left(A_1\right), d'\left(A_2\right), ..., d'\left(A_n\right)\right)^T,\ A_i\left(i=1,2,...,n\right). \tag{8}$$

To reduce each criterion to the range or [0,1] and thus, compare the result. By normalizing, the normalized weight vector were obtained as in equation (9)

$$W = \left(d\left(A_1\right), d\left(A_2\right), \ldots, d\left(A_n\right)\right)^T \tag{9}$$

Step 10: Analyse the result

The main criteria, sub-criteria and weight vector of students' projects will be multiplied to obtain the total weight vector for each alternative. The total weight vector will be compared to acquire the rank between the alternatives. The best alternative can be determined based on the highest weight vector.

3 Numerical Implementation

Step 1: Select a group of respondents

In this study, three lecturers were selected for the decision-making process. Lecturers were selected based on their experience of evaluating students' projects.

Step 2: Break down the problems into hierarchy

As shown in Figure 2.

Step 3: Data Collection (Questionnaire)

The questionnaire was prepared based on criteria and sub-criteria as shown in Figure 2. Three lecturers were requested to answer the questionnaire. The questionnaire consists of 78 questions according to the criteria and sub-criteria of projects.

With respect to: The overall goal		Importance of one main- criterion over another									
Question	Criteria	(3.5, 4.25, 5) Absolutely Important	(2.5, 3.25, 4) Very strongly Important	(1.5, 2.25, 3) Strongly Important	(0.5, 1.25, 2) Weakly Important	(1, 1, 1) Equally Important	(0.5, 1.25, 2) Weakly Important	(1.5, 2.25, 3) Strongly Important	(2.5, 3.25, 4) Very Strongly Important	(3.5, 4.25, 5) Absolutely Important	Criteria
Q1	Content (C_1)			/							Design (C_2)
Q2	Content (C_1)				/						Technical (C_3)
Q3	Content (C_1)					/					Presentation (C_4)
Q4	Design (C_2)						/				Technical (C_3)
Q5	Design (C_2)								/		Presentation (C_4)
Q6	Technical (C_3)							/			Presentation (C_4)

Figure 4: Example of Questionnaire Answered by Experts

Step 4: Generate pair-wise comparison

A pair-wise comparison matrix was created based on expert responses, with answers converted into Triangular Fuzzy Numbers (TFNs) from Table 1. If a preference is marked on the left, the left-hand criterion is more important, and vice versa. For example, in comparing C1 and C2 (Figure 4), experts marked "strongly important" for C1 over C2, resulting in a TFN of (1.5, 2.25, 3). The diagonal uses (1,1,1), and the matrix is filled accordingly.

$$\begin{array}{ccc} \text{criteria} & C1 & C2 \\ C1 & & \\ C2 & & \end{array} \quad \begin{pmatrix} (1,1,1) & (1.5, 2.25, 3) \\ & (1,1,1) \end{pmatrix}$$

Next, the matrix above will have a transformation in which it will change into reciprocal TFN or reversed TFN as shown below.

$$\begin{array}{ccc} \text{criteria} & \text{C1} & \text{C2} \\ \begin{array}{c}\text{C1}\\\text{C2}\end{array} & \multicolumn{2}{c}{\begin{pmatrix} (1,1,1) & (1.5,2.25,3) \\ (0.33,0.44,0.66) & (1,1,1) \end{pmatrix}} \end{array}$$

For Expert 1:

$$\begin{array}{c|cccc} \text{criteria} & \text{C1} & \text{C2} & \text{C3} & \text{C4} \\ \text{C1} & (1,1,1,1) & (1.5,2.25,3) & (0.5,1.25,2) & (1,1,1) \\ \text{C2} & (0.33,0.44,0.66) & (1,1,1) & (0.5,0.8,2) & (0.25,0.307,0.4) \\ \text{C3} & (0.5,0.8,2) & (0.5,1.25,2) & (1,1,1) & (0.33,0.44,0.66) \\ \text{C4} & (1,1,1) & (2.5,3.25,4) & (1.5,2.25,3) & (1,1,1) \end{array}$$

For Expert 2:

$$\begin{array}{c|cccc} \text{criteria} & \text{C1} & \text{C2} & \text{C3} & \text{C4} \\ \text{C1} & (1,1,1,1) & (1.5,2.25,3) & (1,1,1) & (0.5,1.25,2) \\ \text{C2} & (0.33,0.44.0.66) & (1,1,1) & (0.5,0.8,2) & (1,1,1) \\ \text{C3} & (1,1,1) & (0.5,1.25,2) & (1,1,1) & (0.2,0.235,0.285) \\ \text{C4} & (0.5,0.8,2) & (1,1,1) & (3.5,4.25,5) & (1,1,1) \end{array}$$

For Expert 3:

$$\begin{array}{c|cccc} \text{criteria} & \text{C1} & \text{C2} & \text{C3} & \text{C4} \\ \text{C1} & (1,1,1) & (1.5,2.25,3) & (2.5,3.25,4) & (1,1,1) \\ \text{C2} & (0.33,0.44,0.66) & (1,1,1) & (0.33,0.44,0.66) & (0.5,0.8,2) \\ \text{C3} & (0.25,0.307,0.4) & (1.5,2.25,3) & (1,1,1) & (1,1,1) \\ \text{C4} & (1,1,1) & (0.5,1.25,2) & (1,1,1) & (1,1,1) \end{array}$$

Step 5: Apply Geometric Mean

In this study, geometric mean developed by [19] was used to aggregate experts' opinion. The geometric mean was calculated using the equation (1). An example of how the average were calculated for row content (C1) are shown below:

$$\tilde{d}_{12}^{10} = \frac{(1.5,2.25,3)+(1.5,2.25,3)+(1.5,2.25,3)}{3} = (1.5,2.25,3)$$

$$\tilde{d}_{13}^{10} = \frac{(0.5,1.25,2)+(1,1,1)+(2.5,3.25,4)}{3} = (1.3333,1.8333,2.3333)$$

$$\tilde{d}_{14}^{10} = \frac{(1,1,1)+(0.5,1.25,2)+(1,1,1)}{3} = (0.8333,1.0833,1.3333)$$

Therefore, fuzzy evaluation matrix for C1, C2, C3 and C4 are given by

$$
\begin{array}{ccccc}
\text{criteria} & C1 & C2 & C3 & C4 \\
\end{array}
$$

$$
\begin{array}{c}
C1 \\ C2 \\ C3 \\ C4
\end{array}
\begin{pmatrix}
(1,1,1) & (1.5,2.25,3) & (1.3333,1.8333,2.3333) & (0.8333,1.0833,1.3333) \\
(0.33,0.44,0.66) & (1,1,1) & (0.4433,0.68,1.5533) & (0.5833,0.7023,1.1333) \\
(0.5833,0.7023,1.1333) & (0.8333,1.5833,2.333) & (1,1,1) & (1.51,0.5583,0.6483) \\
(0.8333,0.9333,1.3333) & (1.3333,1.8333,2.333) & (2,2.5,3) & (1,1,1)
\end{pmatrix}
$$

A Fuzzy Evaluation Matrix was generated by calculating C11 to C43 using equation (2).

Step 6: Calculating synthetic dimension value, S_i

From equations (3) and (4), the new set of (l,m,u) and the inverse were obtained as follows:

$$
\begin{aligned}
\sum_{j=1}^{m} M_{gi}^{j} &= (1+1.5+1.3333+0.8333, 1+2.25+1.8333+1.0833, 1+3+2.3333+1.3333) \\
&= (4.6666, 6.1666, 7.6666)
\end{aligned}
$$

$$
\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = (15.1057, 19.084, 24.8139)^{-1} = \left(\frac{1}{24.8139}, \frac{1}{19.084}, \frac{1}{15.1057}\right) = (0.0403, 0.0524, 0.0662)
$$

For each criteria,

Criteria	$\sum_{j=1}^{m} M_{gi}^{j}$	$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$	**Synthetic Dimension Value,** S_i
C1	(4.6666,6.1666,7.6666)	(0.0403,0.0524,0.0662)	(0.1881,0.3231,0.5075)
C2	(2.3566,2.8223,4.3466)	(0.0403,0.0524,0.0662)	(0.095,0.1479,0.2878)
C3	(2.9266,3.8439,5.1149)	(0.0403,0.0524,0.0662)	(0.1179,0.2014,0.3386)
C4	(5.1663,6.2666,7.6666)	(0.0403,0.0524,0.0662)	(0.2082,0.3284,0.5075)

Hence, for each sub-criteria,

Sub-criteria C11 to C14	**Sub-criteria C21 to C24**
$S_{11} = (0.1651, 0.2863, 0.4433)$	$S_{21} = (0.1464, 0.2549, 0.4280)$
$S_{12} = (0.205, 0.3205, 0.5304)$	$S_{22} = (0.1096, 0.1628, 0.2753)$
$S_{13} = (0.0932, 0.1508, 0.2528)$	$S_{23} = (0.1825, 0.3276, 0.5505)$
$S_{14} = (0.1548, 0.2424, 0.3903)$	$S_{24} = (0.1508, 0.2547, 0.4431)$
Sub-criteria C31 to C34	Sub-criteria C41 to C44
$S_{31} = (0.1997, 0.2980, 0.4084)$	$S_{41} = (0.1631, 0.2738, 0.4254)$
$S_{32} = (0.2136, 0.2784, 0.4281)$	$S_{42} = (0.0953, 0.1252, 0.2407)$
$S_{33} = (0.0780, 0.1086, 0.1539)$	$S_{43} = (0.2726, 0.4475, 0.6784)$
$S_{34} = (0.2136, 0.3150, 0.4281)$	$S_{44} = (0.0901, 0.1535, 0.2659)$

Step 7: Calculate degree of possibility

The calculation and the comparision are shown below:

Row	**Result**		
First row comparison	$V(S_1 \geq S_2)$ $S_1 = (0.1881, 0.3231, 0.5075)$ $S_2 = (0.095, 0.1479, 0.2878)$ $m_2 = 0.3231, m_1 = 0.1479$ $m_2 \geq m_1 \; \therefore satisfied\,(1)$	$V(S_1 \geq S_3)$ $S_1 = (0.1881, 0.3231, 0.5075$ $S_2 = (0.1179, 0.2014, 0.3386$ $m_2 = 0.3231, m_1 = 0.2014$ $m_2 \geq m_1 \; \therefore satisfied\,(1)$	$V(S_1 \geq S_4)$ $S_1 = (0.1881, 0.3231, 0.5075)$ $S_4 = (0.2082, 0.3284, 0.5075)$ $m_2 = 0.3231, m_1 = 0.3284$ $m_1 \geq m_2 \; \therefore not\ satisfied\,(1)$ $l_1 = 0.2082, u_2 = 0.5072$ $u_2 \geq l_1 \therefore not\ satisfied\,(2)$ $otherwise, 0.9826$

The calculation will proceed for all criteria and sub-criteria.

Step 8: Identify the minimum value

The minimum value is for criteria 1 to 4.

Minimum Value, $d'(A_i)$	$d'(C1)$	$d'(C2)$	$d'(C3)$	$d'(C4)$
	0.9826	0.3060	0.5066	1

Step 9: Calculate weight vector and normalization

The normalized weight vector for criteria 1 to 4:

$$W' = (0.9826, 0.3060, 0.5066, 1)^T$$

$$W = (0.3515, 0.1095, 0.1812, 0.3578)$$

The calculation will proceed for all sub-criteria

Step 10: Analyse the result

All alternatives were denoted as A, B and C, respectively. The best alternative can be determined based on the highest weight vector. The calculation of total weight vector is shown in Table 2

Table 2: Total Weight Vector and Ranking

Main Criteria	Criteria Weight Vector, CWV	Sub-criteria	Sub-criteria Weight Vector, SWV	A	CWV x SWV x A	B	CWV x SWV x B	C	CWV x SWV x C
C1	0.3515	C11	0.3126	0.2743	0.0301	0.1767	0.0194	0.5490	0.0603
		C12	0.3574	0.2868	0.0360	0.1940	0.0244	0.5192	0.0652
		C13	0.0786	0.2886	0.0080	0.2866	0.0079	0.4248	0.0117
		C14	0.2517	0.2190	0.0194	0.2333	0.0206	0.5477	0.0485
C2	0.1095	C21	0.2684	0.1739	0.0050	0.2509	0.0073	0.5752	0.0167
		C22	0.1236	0.1407	0.0019	0.4338	0.0059	0.4254	0.0058
		C23	0.3433	0.2495	0.0094	0.3201	0.0120	0.4304	0.0162
		C24	0.2682	0.2932	0.0086	0.2779	0.0082	0.4289	0.0126
C3	0.1812	C31	0.3316	0.1913	0.0115	0.2326	0.0140	0.5761	0.0346
		C32	0.3079	0.2406	0.0134	0.3175	0.0177	0.4418	0.0246
		C33	0	0.2360	0	0.2278	0	0.5361	0
		C34	0.3605	0.3263	0.0213	0.2917	0.0191	0.3821	0.0250
C4	0.3578	C41	0.3188	0.1909	0.0218	0.2158	0.0246	0.6833	0.0779

		C42	0	0.3417	0	0.3022	0	0.3562	0
		C43	0.6812	0.4274	0.1042	0.0031	0.0008	0.5695	0.1388
		C44	0	0.3165	0	0.1120	0	0.5716	0
Total Weight Vectors					0.2906		0.1818		0.5379
Rank					2		3		1

Based on Table 2, the rank was determined by identifying the highest total weight vector to the lowest weight vector.

4 Results and Discussion

The purpose of this study is to compare FAHP with the manual system which is using rubric evaluation for the projects. Three alternatives were evaluated using a rubric by the same experts who evaluated students' projects using FAHP. Marks given by the 3 different experts for 3 different alternatives were calculated by finding their average marks as shown in Table 3.

Table 3: Student's project evaluation using FAHP and manual rubric system

Alternatives	Total Weight Vectors	Percentage (from rubric)	Rank
Alternative 1	0.2906	60.42	2
Alternative 2	0.1818	52.08	3
Alternative 3	0.5379	83.33	1

Based on the results from both methods, the outcome of the rank did not change. Fuzzy AHP eases the process of converting linguistic variables into quantitative marks compared to the manual rubric system. In this case, Alternative 3 is ranked as Rank 1, followed by Alternative 1 and Alternative 2. Furthermore, this system allows for more reliable analyses to be carried out and more precise findings obtained. From the results of the study, based on the weight of the criteria it was found that Criteria 1, which is presentation, is the most influential factor for students to get high marks followed by Criteria 4 which is content.

5 Conclusion

From this study, it is concluded that FAHP helps to evaluate the linguistic variable for decision-makers. This system converts the linguistic variables into fuzzy numbers which are then calculated to receive the final weight marks. Based on both of the calculations, it can be concluded that Alternative 3 is in rank 1, Alternative 1 is in rank 2 and Alternative 2 is in rank 3.

Comparing the results obtained from using the FAHP system and the manual rubric system, it was found that the final ranking does not change which implies that the results obtained from calculating FAHP are plausible. Furthermore, calculating linguistic variables using the FAHP eases the process of translating it into numericals compared to the manual rubric-based. Evaluations using the manual system could be tiring and difficult. This is because it is time-consuming to calculate the numerical process for each of the projects. FAHP allows for error-free calculations and simplifies complex calculation that requires step-by-step evaluation of projects.

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Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

References

[1] A. Cebi and H. Karal, "An application of fuzzy analytic hierarchy process (FAHP) for evaluating students' project," *Educational Research and Reviews*, vol. 12, no. 3, pp. 120–132, 2017.
[2] S. M. Bai and S.-M. Chen, "Automatically constructing concept maps based on fuzzy rules for adapting learning systems," *Expert Systems with Applications*, vol. 35, no. 1–2, pp. 41–49, 2008.
[3] T. L. Saaty, "How to make a decision: the analytic hierarchy process," *European Journal of Operational Research*, vol. 48, no. 1, pp. 9–26, 1990.
[4] D. E. Asuquo and F. E. Onuodu, "A fuzzy AHP model for selection of university academic staff," *International Journal of Computer Applications*, vol. 14, no. 1, pp. 19–26, 2016.
[5] B. Roy, "Multiple criteria decision analysis," *International Series in Operations Research and Management Science (ISOR)*, vol. 233, pp. 19–39, 2016.
[6] W. Ho, "Integrated analytic hierarchy process and its applications: a literature review," *European Journal of Operational Research*, vol. 186, no. 1, pp. 211–228, 2008.
[7] D. Putra, M. Sobandi, S. Andryana, and A. Gunaryati, "Fuzzy analytical hierarchy process method to determine the quality of gemstones," *Advances in Fuzzy Systems*, vol. 2018, pp. 1–6, 2018.
[8] M. A. Iftikhar and A. Siddiqui, "A study on fuzzy AHP method and its applications in a tie breaking procedure," *Global Journal of Pure and Applied Mathematics*, vol. 13, no. 6, pp. 1619–1630, 2017.
[9] M. B. Ayhan, "A fuzzy AHP approach for supplier selection problem: A case study in a gear motor company," *arXiv preprint*, arXiv:1311.2886, 2013.
[10] L. K. Chan, H. Kao, and M. Wu, "Rating the importance of customer needs in quality function deployment by fuzzy and entropy methods," *International Journal of Production Research*, vol. 37, no. 11, pp. 2499–2518, 1999.
[11] L. A. Zadeh, "Fuzzy sets," *Information and Control*, vol. 8, no. 3, pp. 338–353, 1965.
[12] H. Y. Lin, P. Y. Hsu, and G. J. Sheen, "A fuzzy-based decision-making procedure for data warehouse system selection," *Expert Systems with Applications*, vol. 32, no. 3, pp. 939–953, 2007.
[13] A. Mardani et al., "Multiple criteria decision-making techniques and their applications–a review of the literature from 2000 to 2014," *Economic Research – Ekonomska Istraživanja*, vol. 28, no. 1, pp. 516–571, 2015.
[14] M. Zare et al., "Multi-criteria decision making approach in e-learning: A systematic review and classification," *Applied Soft Computing*, vol. 45, pp. 108–128, 2016.
[15] Y. C. Tang and T. W. Lin, "Application of the fuzzy analytic hierarchy process to the lead-free equipment selection decision," *International Journal of Business and System Research*, vol. 5, no. 1, pp. 35–56, 2011.
[16] P. Srihetta and W. Thurachon, "Applying fuzzy analytic hierarchy process to evaluate and select product of notebook computers," *International Journal of Modeling and Optimization*, vol. 2, no. 2, pp. 168–180, 2012.
[17] Z. Sidek, N. M. M. Ramzi, H. Hashim, S. N. F. Mohamed, and M. A. A. M. Kamil, "Comparison of AHP and fuzzy AHP for multi-criteria decision making," *Journal of Mathematics & Computing Science*, vol. 5, no. 1, pp. 15–26, 2019.
[18] C. C. Sun, "A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods," *Expert Systems with Applications*, vol. 37, no. 12, pp. 7745–7754, 2010.
[19] M. B. Ayhan, "A fuzzy AHP approach for supplier selection problem: A case study in a gearmotor company," *International Journal of Managing Value and Supply Chains*, vol. 4, no. 3, pp. 11–23, 2013.
[20] D.-Y. Chang, "Applications of the extent analysis method on fuzzy AHP," *European Journal of Operational Research*, vol. 95, no. 3, pp. 649–655, 1996.