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Article

Implementation of Fuzzy Analytical Hierarchy Process in Ranking Student Learning Achievement

Lilis Widayanti [a]

[a] *Fakultas Teknologi dan Desain, Institut Teknologi dan Bisnis Asia Malang, Malang, 65113, Indonesia*

***Abstract*—One of the important components in determining the right learning strategy is the assessment of student learning achievement. At SMK PGRI 3 Sidoarjo, assessments are not only carried out on academic aspects, but also pay attention to social, spiritual, skills, knowledge, and attendance aspects. However, the assessments carried out still use a system using direct weighting. The ranking system using direct weights has a weakness of subjectivity in the weights based on the assessor's intuition so that the results are less objective. Fuzzy Analytical Hierarchy Process (AHP) can increase objectivity in conducting rankings because the weights become more proportional. This study aims to implement Fuzzy AHP for assessing student learning achievement at SMK PGRI 3 Sidoarjo. This study contributes to the literature on the application of the Fuzzy AHP approach in student ranking and may serve as a foundation for the advancement of increasingly complex decision support systems in academia. The variables involved in Fuzzy AHP for student ranking are social attitude, spiritual attitude, skills, knowledge, and attendance. The final results of the study indicated that the fuzzy AHP based student ranking system produced a match of 45%, with a mismatch rate of 55% compared to the direct weighting system. This indicates that the Fuzzy AHP method is indeed different from the direct weighting system in terms of objectivity. The difference in results is due to the approach in determining the weight of different criteria.**

***Keywords*—assessment, fuzzy ahp, fuzzy logic, learning achievement, smk 3 pgri**

1. Introduction

Improving the quality of education requires accurate assessment of student learning outcomes to identify the most effective learning techniques (Naharudin et al., 2025). Teachers can determine how well students understand the information being taught and identify areas for improvement by administering assessments. Good assessments should consider attitudes and technical skills in addition to academic success. Teachers can use assessment results to modify instructional strategies, provide better guidance, and create lesson plans that better meet students' needs. Good assessments are systematic and objective. Objective assessments can influence student motivation (Leenknecht et al., 2021).

The condition of the learning achievement assessment process at SMK PGRI 3 Sidoarjo utilizes a standard weighting system with Microsoft Excel tools. Although this technique helps in data processing, the system is not always objective. This is because the weighting system is based on the assessor's intuition in determining its weight so that the ranking results are less consistent and do not fully reflect student performance fairly. In addition, the manual process also takes longer and is prone to calculation errors, which can affect the accuracy of the assessment results. Therefore, a more systematic and objective method is needed to improve the quality of student learning outcome rankings.

Related to ranking, there have been several studies related to this. Analytical hierarchy process (AHP) is one method that has been widely used in ranking (Sutrisno et al., 2023; Yanto, 2021). AHP is often used in solving multicriteria decision-making problems (MCDM) (Canco et al., 2021; Chen et al.,

* Corresponding author.
E-mail Address: lilis.widayanti@asia.ac.id (L. Widayanti)

Author E-mail(s): LW (lilis.widayanti@asia.ac.id)

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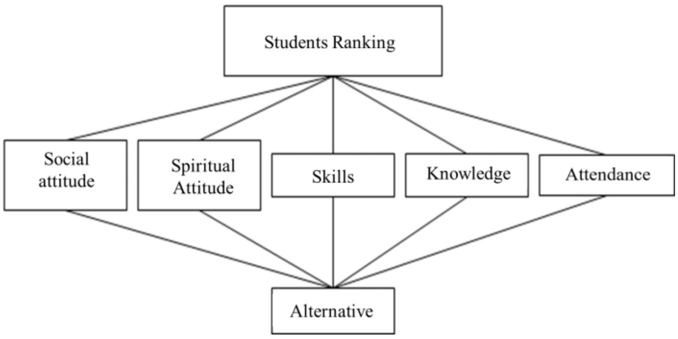

Fig. 1. Hierarchy of ranking of student learning achievement scores

2022). However, the AHP technique shows challenges in managing ambiguity and subjectivity in evaluation, especially when decisions depend on human linguistic preferences. A systematic approach is needed to determine student rankings. Fuzzy AHP is a method that has shown effectiveness in overcoming subjectivity in assessment, as evidenced by various studies (Ahmed & Kilic, 2024). The Fuzzy AHP technique is designed to overcome these limitations by incorporating fuzzy set theory into the pairwise comparison process.

An strategy that can help improve the accuracy and objectivity of student ranking is the Fuzzy Analytical Hierarchy Process (AHP) (Peng, 2022; Goyal et al., 2022; Wu et al., 2022; (Muhammad et al., 2021). This method combines AHP with the concept of fuzzy logic so that it can handle uncertainty in determining the weight of the criteria (Naharudin et al., 2025). Chen conducted a study by comparing the functionality of using fuzzy AHP and regular AHP with the result that for small data matrix sizes, fuzzy AHP will be superior to AHP. As the matrix size increases, the difference between AHP and Fuzzy AHP decreases and can even be ignored if the size reaches a fairly large level (Chen et al., 2022).

Research conducted by Naharudin et al. (2025) successfully identified the optimal route for e-scooters in Bukit Bintang by integrating the Fuzzy-AHP and GIS methods, where route facilities are the most crucial factor in route selection. Research conducted by Xu et al. (2023) emphasized the role of information technology in education during COVID-19 and the effectiveness of Fuzzy AHP in determining the best teaching method by overcoming uncertainty in decision making. Research conducted by Yu (2022) developed a method for evaluating the effectiveness of public art teaching in higher education using AHP-based Fuzzy Comprehensive Evaluation. The results showed that department leaders gave teachers a score of 94.11 for their teaching ability. According to a study by Harahap et al. (2022), the Fuzzy AHP method can be used to rank student understanding and identify the primary criteria that have the greatest impact on it. These criteria include extrapolation criteria and the ability to connect mathematical concepts with novel situations, both of which are crucial for the learning process.

Based on the research information described previously, fuzzy AHP is a method that is considered relevant to helping SMK PGRI 3 Sidoarjo assess students' learning achievement more objectively. By implementing Fuzzy AHP in assessing student learning achievement at SMK PGRI 3 Sidoarjo, it is expected that the problems that arise with the previous ranking system can be resolved. The goal of this research is to investigate how Fuzzy AHP can be utilized to promote objectivity in the student ranking process at SMK PGRI 3 Sidoarjo by taking into account a variety of assessment factors.

Table 1. Student learning achievement

No	Student Initials	K1	K2	K3	K4	K5
1	APP	76,0	87,0	80,56	80,19	5
2	AJM	84,0	86,0	84,69	84,69	1
3	ASF	81,0	86,0	82,50	82,44	2
4	ATS	82,0	86,0	82,00	81,88	5
5	AW	79,0	81,0	82,56	82,25	3
6	BEP	77,0	81,0	80,56	80,13	5
7	BDR	85,0	87,0	85,75	85,13	0
8	BSN	76,0	81,0	79,31	78,81	5
9	BYR	77,0	81,0	79,50	78,94	5
10	DAR	81,0	83,0	82,31	81,75	2
11	FA	81,0	87,0	83,56	82,81	1
12	FR	85,0	87,0	84,50	83,75	0
13	FF	86,0	87,0	84,81	84,44	3
14	FM	83,0	87,0	83,94	83,56	2
15	FR	85,0	87,0	83,75	83,19	0
16	FIA	83,0	87,0	83,56	83,38	1
17	FDP	86,0	87,0	82,75	82,81	2
18	HRP	80,0	83,0	83,31	82,94	1
19	HAN	79,0	83,0	82,38	82,00	3
20	IDE	79,0	83,0	83,75	83,38	0

2. Research Method

In this investigation, the fuzzy AHP technique will be applied to rank student learning achievement based on various predetermined criteria. Several main stages of this method, namely data collection, implementation of the Fuzzy AHP algorithm, and testing aim to ensure that the assessment of student learning achievement is carried out systematically, objectively, and effectively.

2.1. Data Collection

This study uses student value data that includes social attitudes with code K1, spiritual attitudes with code K2, skills with code K3, knowledge with code K4, and attendance with code K5. Fig. 1 provides an illustration of the ranking hierarchy.

Based on the Fig. 1, the student rating system consists of three levels. The first level is Students Ranking, which serves as the primary goal of determining ranks using stated criteria. The second level has five assessment criteria: Social Attitude assesses students' interactions in social settings; Spiritual Attitude assesses spiritual principles and morality; Skills assess students' practical abilities; Knowledge assesses academic understanding; and Attendance considers the impact of attendance on performance. The third level is Alternatives, which represents a list of students evaluated according to their performance in each category, resulting in a more objective and systematic ranking method.

Table 1 below shows the value of one of the classes at SMK PGRI 3 Sidoarjo, which is used as a case study in this study. The "Student Initials" column shows the anonymized identity of the students, while the scores for each criterion reflect their abilities across all components measured.

In addition to student grade data, the ranking of student achievement grades requires grade conversion data, as shown in Table 2.

Table 2. Scale for value conversion

Criteria	Sub-Criteria	Scale
Social Attitude	Excellent (SB) Good (B) Fair (C) Poor (K)	91 - 100 83 - 90 75 - 82 < 75
Spiritual Attitude	Excellent (SB) Good (B) Fair (C) Poor (K)	91 - 100 83 - 90 75 - 82 < 75
Skills	-	0 - 100
Knowledge	-	0 - 100
Attendance	Excellent (SB) Good (B) Fair (C) Poor (K) Very Poor (SK)	0 1-2 3-4 5 > 5

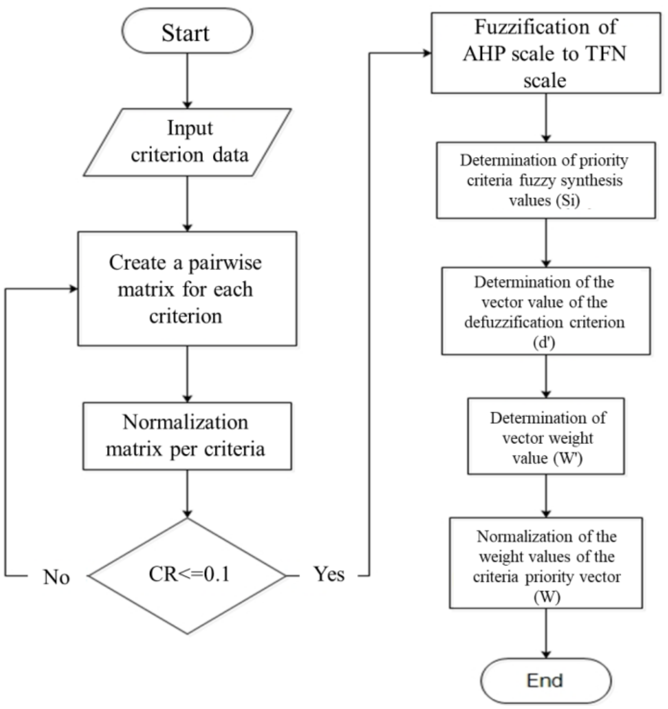

Fig. 2. Fuzzy AHP process for ranking

2.2. Implementation of Fuzzy AHP method

Fig. 2 illustrates the procedure for determining the criteria weight using the Fuzzy AHP approach. This procedure begins with entering the criteria data, followed by the formulation of a pairwise comparison matrix using the AHP scale. The data is normalized and tested for consistency (CR ⩽ 0.1). Then, it is fuzzified to the Triangular Fuzzy Number (TFN) scale to find the priority weight for the criteria. The next stages include calculating the fuzzy synthesis value, defuzzification, and normalizing the priority weight as the final result.

Based on the fuzzy AHP flowchart as in Fig. 2, the fuzzy AHP calculation flow can be explained as follows.

2.2.1. Creating a pairwise matrix between criteria.

The level of importance between criteria in the Fuzzy AHP method follows the linguistic set shown in Table 3 (Chang, 1996; (Safiesza et al., 2024). In the linguistic set, each level of importance is represented by a Triangular Fuzzy Number (TFN) value and its inverse value. This scale helps in determining the relative weight of the factors evaluated in pairs, resulting in more accurate and adaptable decisions in ambiguous situations.

Table 3. Triangular Fuzzy Number (TFN)

Level of Importance	Linguistic Set	Triangular Fuzzy Number (TFN)	Reciprocal (Inverse)
1	Just equal comparison of elements	(1, 1, 1)	(1, 1, 1)
2	Intermediate	(1/2, 1, 3/2)	(2/3, 1, 2)
3	One element is moderately more important than the other	(1, 3/2, 2)	(1/2, 2/3, 1)
4	Intermediate	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
5	One element is strongly more important than the other	(2, 5/2, 3)	(1/3, 2/5, 1/2)
6	Intermediate	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
7	One element is very strongly more important than the other	(3, 7/2, 4)	(1/4, 2/7, 1/3)
8	Intermediate	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)
9	One element is extremely more important than the other	(4, 9/2, 9/2)	(2/9, 2/9, 1/4)

Table 4 arranges pairwise comparisons between criteria in the Fuzzy AHP method. Triangular Fuzzy Number (TFN) has three parameters, namely *lower* (l), *middle* (m), and *upper* (u).

Table 4. TFN format

Criteria	Criteria 1	Criteria 2	Criteria 3
Criteria 1	(1,1,1)	(l, m, u)	(l, m, u)
Criteria 2	(l, m, u)	(1,1,1)	(l, m, u)
Criteria 3	(l, m, u)	(l, m, u)	(1,1,1)
.....			
Criteria *i*	.....	.....	.....

2.2.2. The Consistency Ratio (CR)

The Consistency Ratio (CR) formula in FAHP assesses the consistency of pairwise comparisons. The calculation of CR is performed using (1).

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{1}$$

where CI is Consistency Index which calculated using (2).

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

where n represents the number of criteria and $\lambda_{\max}$ is maximum eigen value of pairwise comparison. RI stands for Random Index, whose value is determined by the number of criterions n and may be found in the Table 5.

If $CR \leq 0.1$, then the consistency level is acceptable. Otherwise, if $CR > 0.1$, then the comparison matrix is less consistent and needs to be improved.

2.2.3. Determining the value (S_i) or fuzzy synthesis

At this stage, the fuzzy synthesis value (S_i) is calculated, namely the sum of the lower, middle, and upper values in the TFN matrix. The purpose of this process is to obtain a cumulative value for each criterion used in the analysis. Finding the S_i value lets the Fuzzy AHP method take uncertainty into account during the evaluation process, which leads to a more accurate priority weight. The value of S_i is determined using (3).

$$S_i = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right) \times \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{3}$$

where
l_{ij}, m_{ij}, u_{ij} = Triangular fuzzy number values from the pairwise comparison matrix
n = number of criteria
i, j = index of criteria

2.2.4. Defuzzification

Determining the priority vector value d' means comparing one criterion with another. The (4) shows how to determine the value of the priority vector.

$$V(S_i \geq S_k) = \begin{cases} 1 & \text{, jika } m_i \geq m_k \\ 0 & \text{, jika } l_2 \geq u_1 \\ \dfrac{(l_k - u_i)}{(m_i - u_i) - (m_k - l_k)} & \text{, jika } m_i < m_k \end{cases} \tag{4}$$

where, l_i, m_i, u_i is the triangular fuzzy values for criterion i (Lower, Middle, Upper). Whereas l_k, m_k, u_k is the triangular fuzzy values for k criterion (Lower, Middle, Upper).

After comparing all the criteria pairs, the next step is to calculate the priority value d' with the following conditions:

$$d_i' = \min V(S_i \geq S_k) \tag{5}$$

where i being the index of criterion; and S_i and S_k is the fuzzy synthesis value obtained previously.

2.2.5. Determining the value of the vector W'

The value of vector W' can be defined by taking the minimum value from the results of the d' process, as in (6).

$$W' = (d_i') = (d_1', d_2', \ldots, d_n') \tag{6}$$

where n indicating the number of criteria.

2.2.6. Determining the W vector value

The W vector value is the W' value which has been normalized and used as a criteria weight vector. Equation (7) computes the initial weight derived from the defuzzification outcomes, whereas (8) standardizes the weight to ensure the total sum equals 1.

$$W_i = \frac{W_i'}{\sum_{j=1}^{n} W_j} \tag{7}$$

$$\sum W = 1 \tag{8}$$

where
W_i = Normalized weight of criterion i
W_i' = Criteria weight i
i, j = index of criteria
n = the number of criteria

2.2.7. Testing

To verify that the method used provides satisfactory results, the ranking results are compared with alternative methods or with manual assessments carried out by experts, such as teachers or educators. The validation process involves comparing the Fuzzy AHP ranking results with the rankings given by teachers, which are based on their experience in assessing students.

Table 5. Value of random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 6. Fuzzification process results

Criteria	l	m	u
K1	0,189	0,306	0,469
K2	0,193	0,306	0,490
K3	0,088	0,156	0,265
K4	0,084	0,139	0,245
K5	0,063	0,094	0,150

3. Results and Discussion

3.1. Implementation Results

This section describes the results of the implementation of the Fuzzy AHP method, which includes the processes of fuzzification, defuzzification, weight normalization, and ranking. Fuzzification converts the criteria into triangular fuzzy numbers, then defuzzification converts the numbers into crisp values. After weight normalization is performed, the ranking process is carried out to determine priorities based on the specified criteria. The following sections describe the results of each stage.

3.1.1. Fuzzification Results

The results of the process of determining the paired matrix and calculating the fuzzy synthesis value, produce Table 6 which shows the fuzzification results consisting of three parameters lower (l), middle (m), and upper (u).

Table 7 indicates that the fuzzy membership values for K1 and K2 are the highest, indicating that these two criteria have a greater weight in the assessment process. K5 shows the lowest fuzzy membership value, indicating a reduced influence on the final decision.

Table 7. Priority values of defuzzification results

Criteria	Defuzzification Calculation	d'
K1	Min (1; 1; 1; 1)	1
K2	Min (1; 1; 1; 1)	1
K3	Min (0,336; 0,324; 1; 1)	0,324
K4	Min (0,250; 0,236; 0,901; 1)	0,236
K5	Min (0; 0; 0,497; 0,593)	0

Table 8. Results of weighting of all criteria

Criteria	W_i'	W_i
K1	1	0,391
K2	1	0,391
K3	0,324	0,127
K4	0,236	0,092
K5	0	0

3.1.2. Defuzzification

Table 7 details the defuzzification results, showing that K1 and K2 have the highest defuzzification values of 1, indicating that they are critical. Simultaneously, K3, K4, and K5 have lower defuzzification values of 0.324, 0.236, and 0, respectively, indicating that they have less importance in the assessment procedure.

3.1.3. Weight normalization

Table 8 details the defuzzification results, showing that K1 and K2 have the highest defuzzification value of 1, indicating that K1 and K2 are very important. While K3, K4, and K5 have lower defuzzification values of 0.324, 0.236, and 0, respectively, indicating that these criteria have little importance in the assessment procedure.

Once we have established the weight of all criteria, we proceed to calculate the weight of each sub-criteria. The steps used are the same as the steps in finding the weight of the criteria. Table 9 shows the results of finding all the weights of the criteria and each of their subcriteria.

Based on Table 9, the sub-criterion "Very Good (A)" has the highest weight, which is 0.669 for K1 (Social Attitude) and K2 (Spiritual Attitude), followed by the category "Good (B)" with a weight of 0.331. Other sub-criteria are valued at 0. The sub-criterion "Very Good (A)" has the highest weight, which is 0.663 for K5 (Attendance), while the sub-criterion Good (B) has a higher weight, and the others have a weight value of 0. With these weights, we can start to rank the students based on how well they meet each criterion and sub-criterion.

3.1.4. Ranking

The next step after the weight of the criteria and sub-criteria is to rank the student data. The first step in ranking is to convert the values using scale in Table 2. From this conversion, a conversion is carried out into the weights in Table 9. To get the final value of each student, an average calculation is carried out, the results of which are shown in Table 10.

With the highest average achievement of 0.084639, students with the initials BDR are ranked first as shown in Table 10. AJM and FF are in second and third place, with very small differences

Table 9. Weight of all criteria and each criterion

No	Criteria Code	Criteria Name	Weight	Sub-criteria	Category Weight
1	K1	Social Attitude	0,391	SB	0,669
				B	0,331
				C	0,000
				K	0,000
2	K2	Spiritual Attitude	0,391	SB	0,669
				B	0,331
				C	0,000
				K	0,000
3	K3	Skills	0,127	-	-
4	K4	Knowledge	0,092	-	-
5	K5	Attendance	0,000	SB	0,663
				B	0,337
				C	0,000
				K	0,000
				SK	0,000

Table 10. Priority values of defuzzification results

Student Initial Name	Average Student Achievement	Ranking
BDR	**0,084639**	**1**
AJM	0,084534	2
FF	0,084529	3
FR	0,084466	4
FM	0,084413	5
FR	0,084378	6
FIA	0,084374	7
FDP	0,084280	8
IDE	0,035513	9
FA	0,035467	10
HRP	0,035455	11
ASF	0,035365	12
HAN	0,035331	13
DAF	0,035312	14
ATS	0,035300	15
APP	0,035091	16
AW	0,010921	17
BEP	0,010650	18
BYR	0,010502	19
BSN	0,010480	20

in results. This shows tight competition between high-achieving students. However, with the lowest average achievement value of 0.010480, students with the initials BSN are ranked last. With relatively low scores compared to other students, BYR and BEP are also in last place.

3.2. Test results

A comparison of student rankings based on the old assessment system and the new system determined by the Fuzzy AHP approach is shown in Table 11.

Fig. 3 illustrates a notable disparity between the traditional technique and FAHP in establishing student rankings, with more pronounced jaw values in the FAHP methodology. This signifies that the FAHP system exhibits greater sensitivity to fluctuations in evaluation factors than the previous system. This study seeks to enhance the efficacy of FAHP in delivering more

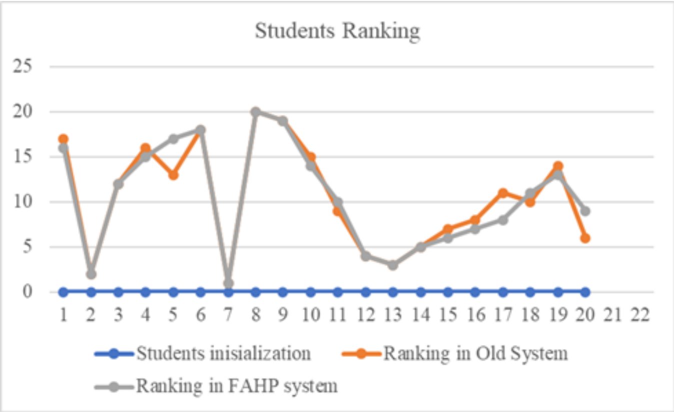

Fig. 3. Visualization of students ranking

objective and equitable ranking outcomes.

The comparison examination of the previous system and the Fuzzy AHP approach revealed that 9 students maintained constant rankings, but the remaining students underwent alterations. Certain pupils, like IDE, FDP, and FA, witnessed an elevation in their rankings, but others, such as AW, ATS, and HAN, encountered a decline. BDR retained its leading position, whilst BSN sustained its last position in both systems. The alterations in rankings suggest that the Fuzzy AHP method offers a more systematic framework for establishing student weights and rankings, leading to a more impartial assessment compared to the previous system.

$$\text{The match percentage} = \frac{\text{The Number of Matching Data}}{\text{The Number of Data}} * 100\%$$

$$= \frac{9}{20} * 100\%$$

$$= 45\%$$

The calculation results indicate that the level of match between the old system and the Fuzzy AHP method reaches 45%, with 11 out of 20 data that do not match the school ranking, or there are 55% of data that do not match. The difference in ranking results between the old system and the Fuzzy AHP method arises from differences in methodology in determining weights and the decision-making process. In the previous approach, weights were given directly, which were sometimes subjective and failed to take into account uncertainty in the evaluation. The Fuzzy AHP method uses a fuzzy logic approach that effectively accommodates ambiguity in the assessment of criteria.

4. Conclusion

The findings of the investigation suggest that the Fuzzy AHP method can enhance objectivity in the student ranking process in contrast to the direct weighting method, which remains subjective. By taking into account the assessment of social, spiritual, and attendance criteria, this method enables a more proportional determination of the weights of the criteria. Social attitudes and spiritual attitudes are weighed at 30.2% and 25.7%, respectively, in comparison to skills (20.1%), knowledge (15.6%), and attendance (8.4%). This suggests that non-academic factors are significant in assessing student achievement. Fuzzy AHP is implemented in this investigation through the following stages: data acquisition, pairwise comparison matrix formation, fuzzification, defuzzification, and weight normalization. In comparison to the direct weighting system, this method generates a 45% match rate, with a 55% mismatch rate, as indicated by the final results.

Table 11. Ranking of student achievement

No.	Student initials	Old system		New system (Fuzzy AHP Method)	
		Score	Ranking	Score	Ranking
1	**APP**	**80,38**	**17**	**0,035052**	**16**
2	AJM	84,69	2	0,084458	2
3	ASF	82,47	12	0,035326	12
4	**ATS**	**81,97**	**16**	**0,035261**	**15**
5	**AW**	**82,41**	**13**	**0,010900**	**17**
6	BEP	80,34	18	0,010629	18
7	BDR	85,44	1	0,084563	1
8	BSN	79,06	20	0,010460	20
9	BYR	79,22	19	0,010482	19
10	**DAR**	**82,03**	**15**	**0,035273**	**14**
11	**FA**	**83,19**	**9**	**0,035428**	**10**
12	FR	84,13	4	0,084391	4
13	FF	84,63	3	0,084453	3
14	FM	83,75	5	0,084337	5
15	**FR**	**83,47**	**7**	**0,084302**	**6**
16	**FIA**	**83,47**	**8**	**0,084298**	**7**
17	**FDP**	**82,78**	**11**	**0,084205**	**8**
18	**HRP**	**83,13**	**10**	**0,035416**	**11**
19	**HAN**	**82,19**	**14**	**0,035292**	**13**
20	**IDE**	**83,56**	**6**	**0,035474**	**9**

Nevertheless, this investigation suffers from several constraints, including the fact that the number of samples is restricted to a single school and the initial weights are determined by subjective data from instructors. Further research is advised, including the integration of the Fuzzy AHP method with machine learning techniques to enhance the accuracy of automatic ranking and the testing of this model on a broader array of institutions.

The Fuzzy AHP method has a weakness in its calculations, which are more complicated than the classical AHP method, so a decision support system is suggested for future research so that education practitioners can use it more simply. In addition, the assessment process becomes faster, more accurate, and more systematic.

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Lilis Widayanti is a lecturer in the Computer Systems study program at Institut Teknologi dan Bisnis Asia Malang (ITB Asia), Malang City, Indonesia. She teaches courses in mathematics, numerical methods, statistics and probability, and models and simulations. Lilis is currently pursuing her Doctoral Education in the Department of Informatics and Electrical Engineering at the State University of Malang.