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Comparison Analysis of *AHP-SAW*, *AHP-WP*, *AHP-TOPSIS* Methods in Private Tutor Selection

Ni Komang Yanti Suartini
Universitas Pendidikan Ganesha/Computer Science Department, Singaraja, 81116, Indonesia
E-mail: yanti.suartini@undiksha.ac.id
ORCID iD: https://orcid.org/0000-0001-6949-7498

Dewa Gede Hendra Divayana*
Universitas Pendidikan Ganesha/Informatics Education Department, Singaraja, 81116, Indonesia
E-mail: hendra.divayana@undiksha.ac.id
ORCID iD: https://orcid.org/0000-0001-7096-3396
*Corresponding Author

Luh Joni Erawati Dewi
Universitas Pendidikan Ganesha/Computer Science Department, Singaraja, 81116, Indonesia
E-mail: joni.erawati@undiksha.ac.id
ORCID iD: https://orcid.org/0000-0003-3041-731X

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Abstract: Private tutoring was a non-formal education, it was used as an alternative by parents to help support and maximize the learning process that students get at school. Sometimes parents have difficulty in adjusting the desired and needed criteria with available alternatives or teachers. To overcome these obstacles, this research used the *MADM* approach in providing alternative recommendations, based on the criteria used as the basis for decision making. *MADM* consists of *SAW, WP, TOPSIS*, and *AHP*. The advantages of the *SAW*, *WP*, and *TOPSIS* methods in managing cost and benefit data were used in the ranking process. While the weaknesses of the three methods in the weighting process can be overcome by the *AHP* method, which was able to provide more objective weighting results. Therefore, this research aimed to analyze the comparison of the combination of *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* methods in the selection of private tutors. The combination of these methods was compared based on accuracy, ranking, and preference to get the best combination of *MADM* methods in determining the selection of private tutors. The criteria used in this research were education, experience, cost, duration, rating, and distance. The comparison of the three combinations of methods showed the *AHP-SAW* method has an accuracy rate of 88.14%, *AHP-WP* of 68.64%, and *AHP-TOPSIS* of 66.95%. The average ranking showed the *AHP-SAW* method gave results of 91%, *AHP-WP* of 88%, and *AHP-TOPSIS* of 89%. In addition, the average preference showed the *AHP-SAW* method gave a value of 0.771, *AHP-WP* of 0.073, and *AHP-TOPSIS* of 0.564. Thus, it showed the *AHP-SAW* gave better results in the case of private tutor selection than the *AHP-WP* and *AHP-TOPSIS*.

Index Terms: *AHP, SAW, TOPSIS, WP*, Private Tutor.

1. Introduction

Private tutoring is an effective non-formal education in supporting the success of the student learning process [1]. This service was used as an alternative by parents of students in meeting the educational needs of their children. Sometimes parents have difficulty in adjusting the desired and needed criteria with available alternatives or teachers, which then causes cases of sudden dismissal or changing of tutors. To overcome these obstacles, this research needs a method or approach that can involve many criteria as a basis for decision-making. The method that can be used is *Multi-Attribute Decision Making* (*MADM*) [2,3]. In addition to involving many criteria, *MADM* is also appropriate for cases involving many alternatives. Based on its objectives, the essence of *MADM* is to determine the weight value, then proceed with ranking to select alternatives [4-6]. The method used to solve the *MADM* problems are *Simple Additive*

Weighting (*SAW*), *Weighted Product* (*WP*), *Technique for Order Preference Similarity to Ideal Solution* (*TOPSIS*), and *Analytical Hierarchy Process* (*AHP*).

In the case of a private tutor selection, it involved a variety of cost and benefit data. This was to the advantage of the *SAW*, *WP*, and *TOPSIS* methods which can handle cost and benefit data simultaneously. So, it was appropriate if the three methods were used. In addition to having advantages in managing cost and benefit data, the three methods have a weakness in the process of assigning weights. This was because there were no experts/sources who can determine the exact initial weight of each criterion. The weakness of the three methods can be overcome with the *AHP* method. The *AHP* method is part of the *MADM* which has the advantage of being able to provide more objective weighting results because it used a comparison of the *Saaty* scale value (1-9) and measured consistency parameters [7,8]. However, the *AHP* method was not appropriate if used for the ranking process because the calculation process does not distinguish between cost and benefit data. So, it was only used for the weighing process.

Based on this explanation, the purpose of this study was to compare the combination of *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* methods in providing recommendations for the results of private tutoring decisions for parents and students. *AHP* was intended to find the weight of each criterion because it can provide a more objective weighting result. *SAW*, *WP*, and *TOPSIS* were intended to rank each alternative because it’s can handle cost and benefit data simultaneously. The combination of these methods was compared based on accuracy, ranking, and preference. Thus, the best combination of methods in *MADM* was obtained for determining the case for private tutor selection.

2. Basic Theory

A. Multi-Attribute Decision Making (MADM)

The *Multi-Attribute Decision Making* (*MADM*) method is a decision-making method to determine the best alternative based on certain criteria. Criteria are in the form of rules/standards used in decision-making. There are three stages carried out in the *MADM* process, namely the preparation of the components of the situation, analysis, and synthesis of information. The methods used in solving *MADM* problems are *Simple Additive Weighting* (*SAW*), *Weighted Product* (*WP*), *Technique for Order Preference Similarity to Ideal Solution* (*TOPSIS*), and *Analytical Hierarchy Process* (*AHP*)[9].

B. Analytical Hierarchy Process (AHP)

The *AHP* mechanism is the simplification of a complex problem into its parts, then organizing it in a hierarchy [10-22]. The following are the steps in implementing the *AHP* method:

1) Determine the value of the criteria using pairwise comparisons based on the *Saaty* scale of 1-9. This data becomes a data matrix.

Table 1. Saaty Scale

Intensity of importance	Definition
1	Equal (equally important)
3	Moderate (moderately/weakly/slightly more important)
5	Strong (strongly more important)
7	Very strong (very strongly/demonstrably more important)
9	Extremely/more important
2, 4, 6, 8	The values between the two adjacent judgments

2) Determine the priority weight scale
   - Divide each value from the column by the corresponding column total to obtain a normalized matrix. The resulting data is data normalization.
   - Add up the values of each row and divide by the number of elements to get the average value. The data generated is priority data for every criterion

3) Determine the consistency ratio
   - Multiply each value in the first column by the relative priority of the first element, the value in the second column by the relative priority of the second element
   - Sum each row
   - The result of the row sum is divided by the corresponding relative priority element

$$\lambda \text{ max} = \text{total/total criteria used} \quad (1)$$

$$CI = (\lambda \text{ max} - n) / (n-1) \quad (2)$$

$$CR = CI / IR \tag{3}$$

- If CR value ≤ 0.1 then the assessment is declared consistent, but if CR > 0.1 then the assessment must be corrected

Description:

- λ max: eigen value maximum
- CI: consistency index
- CR: consistency ratio
- IR: index random

Table 2. Index Random

Total Matrix	IR Value
1,2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

C. Simple Additive Weighting (SAW)

SAW is a method that looks for the weighted summation of the performance ratings on each alternative [23-30]. Several things need to be considered in applying the *SAW* method.

1) The *SAW* method requires the process of normalizing the decision matrix (X) to a scale that can be compared with all existing alternative ratings. The formula to perform the normalization is as follows.

$$r_{ij} = \begin{cases} \frac{x_{ij}}{\text{Max}_i \, x_{ij}} & if\ j\ is\ benefit\ attribute \\ \frac{\text{Min}_i \, x_{ij}}{x_{ij}} & if\ j\ is\ cost\ attribute \end{cases} \tag{4}$$

Description:
r_{ij}: normalized performance rating
Max_{ij}: the highest value of each row and column
Min_{ij}: the lowest value of each row and column
X_{ij}: row, and column of the matrix

2) The preference value for each alternative (V_i)

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \tag{5}$$

Description:
V_i = preference weight value of each alternative
W_j = criterion weight value
r_{ij} = performance rating value
A larger V_i value indicates that alternative A_i is preferred.

D. Weighted Product (WP)

WP uses multiplication to relate attribute ratings. Normalization is carried out using rating each attribute to the power of the weight of the attribute in question [7]. Several things need to be considered in the *WP* method.

1) Normalize the criteria weights

The preference for A_i is given as follows:

$$S_i = \prod_{j=1}^{n} x_{ij}{}^{w_j} \tag{6}$$

W_j is a positive rank for the benefit attribute and a negative value for the cost attribute.

$$w_j = \frac{w_j}{\sum w_j} \tag{7}$$

2) The relative preference of each alternative, is given as:

$$V_i = \frac{\prod_{j=1}^{n} w_j x_{ij}}{\prod_{j=i}^{n} \left(x_j^*\right)^{W_j}} \tag{8}$$

A larger V_i value indicates that the alternative Ai is preferred.

E. Technique for Others Reference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multi-criteria decision-making method. Based on a geometric point of view, where the chosen alternative must have the furthest distance from the negative ideal solution and the closest to the positive ideal solution [3, 31-43]. The following are the stages of applying the *TOPSIS* method.

1) Create a normalized decision matrix

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{9}$$

2) Create a Y-weighted normalized decision matrix

$$y_{ij} = W_i \times r_{ij} \tag{10}$$

3) Determine the positive ideal solution matrix & negative ideal solution matrix

$$A^+ = \left(y_1^+, y_2^+, \cdots, y_n^+\right)$$
$$A^- = \left(y_1^-, y_2^-, \cdots, y_n^-\right) \tag{11}$$

$$y_j^+ = \begin{cases} \max_i y_{ij}; & if\ j\ is\ benefit\ attribute \\ \min_i y_{ij}; & if\ j\ is\ cost\ attribute \end{cases}$$

$$y_j^- = \begin{cases} \min_i y_{ij}; & if\ j\ is\ benefit\ attribute \\ \max_i y_{ij}; & if\ j\ is\ cost\ attribute \end{cases} \tag{12}$$

4) Determine the distance between the value of each alternative with the positive ideal solution matrix & the negative ideal solution matrix

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(y_i^+ - y_{ij}\right)^2}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_i^-\right)^2} \tag{13}$$

5) Determine the preference value for each alternative.

$$V_i = \frac{D_i^-}{D_i^- + D_i^+} \tag{14}$$

A larger V_i value indicates that the alternative A_i is preferred.

3. Literature Review

This research was motivated by research conducted by Nugraha and Mahendra [44], which compared the combination of the *AHP-SAW* method with *AHP-WP* in determining the best e-commerce in Indonesia. Although it gave different final results because it used different normalization procedures, this research proved that the application of the *AHP* method was able to provide more objective weighting results. It was different from the results of research conducted by Ardiyanto [45], which compared the combination of the *AHP-TOPSIS* and *AHP-WP* methods in helping to provide the right solution so that the decision to grant PMW funds was by the specified criteria. The results of the research conducted showed that *AHP-WP* has a better accuracy rate than *AHP-TOPSIS*. In connection with the use of the *AHP* method as a weighting process at the beginning of all combinations, the researchers tried to compare the three methods that will be used in the ranking process on alternatives, namely *SAW*, *TOPSIS*, and *WP*. From the results of research conducted by Supiyan [46], which compared the *SAW*, *WP*, and *TOPSIS* methods in helping and reducing subjective assessments in determining to finance. The results of this research indicate that the *WP* method was more accurate than the *SAW* and *TOPSIS* methods. Then it was different from the results of research conducted by Marbun [4], who analyzed the application of the *SAW*, *WP*, and *TOPSIS* methods to a decision support system in universities. The results of this research indicate that *SAW* and *WP* give the same and different ranking results from the results obtained using the *TOPSIS* method. The next research was conducted by Hadikurniawati *et al*. [47], which examines the *MADM* method in selecting outstanding students. The results of this research indicate that *AHP-TOPSIS* gives better results than *WP* and *SAW*. This study also proves that the application of the *AHP* method in the weighting process provides objective weighting results so that it has an impact on better decision results, rather than directly using the *SAW*, *WP*, and *TOPSIS* methods. Further related research using the same case example using the *AHP-SAW* method by Suartini *et al.* [1], shows that a combination of these methods can be used in determining the selection of private tutors. However, this research only used a combination of the *AHP-SAW* method, without comparing it with other combinations of methods. The criteria used in this research are education, cost, experience, discipline, and assessment/rating of teaching methods. This study also proves that the application of the *AHP* method was able to provide more objective weighting results, and the selection of methods in the ranking process was adjusted to the type of criteria used.

4. Method

The flow of this research used 4 stages. These stages were literature study, data collection, data processing, and analysis. The stages of the research flow was shown in Fig.1.

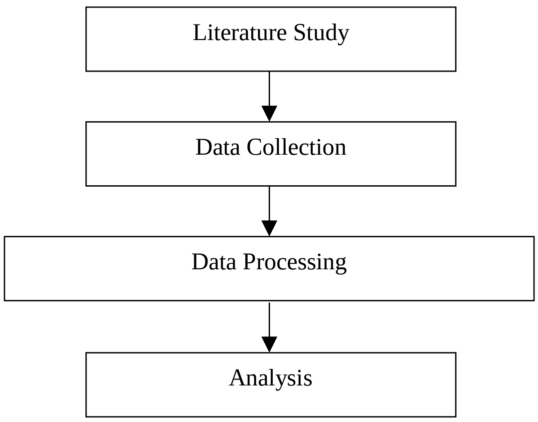

Fig. 1. Research Flow

A. Literature Study

In the first stage, the researcher determined the method that can be used in the case of selected private tutors in various literature sources such as journals, articles, and physical or electronic books. From this analysis, the method that can be used in the case of private tutor selection was *MADM*. *MADM* was a capable method that involved many criteria as a basis for decision-making. Part of the *MADM* method was *SAW*, *WP*, *TOPSIS*, and *AHP*. Based on the advantages and disadvantages of each method, *AHP* was used in the weighting process, while *SAW*, *WP*, and *TOPSIS* were used in the ranking process.

B. Data Collection

Researchers collected data from interviews in a private tutoring place, and direct observation through the distribution of questionnaires filled out by 15 private tutors and 118 students and parents. Several criteria were commonly used as indicators by private tutoring service providers. The criteria were subject, level, gender, marital status, choice of place (tutors come to students' homes or students come to tutoring sites), tutoring time, education, experience, cost, duration, distance, and rating. The criteria that can be used for the weighting process are education, experience, cost, duration, ranking, and distance. While the other criteria were more appropriate to enter into the filtering process because there was no rate, that can define the type and value of these criteria. In determined tutors, prospective service users can be used several existing criteria to be adapted to the conditions, needs, and desires of service users.

C. Data Processing

The calculation starts from the weighting process with the *AHP* method. The inputted weights were based on the *Saaty* scale (1 to 9). At the weighting stage with the *AHP* method, a consistency ratio (CR) check was carried out. If CR > 0.1, then the weighting process must be repeated because it was considered inconsistent. If the results of the CR weighting ⩽ 0.1, then the calculation process continued to rank with the *SAW*, *WP*, and *TOPSIS* methods as shown in Fig.2.

Fig. 2. Flowchart Diagram of Combination Calculation of *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* Methods

The results from the combination of the *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* methods will provide ranking results and preference values. These results will be compared to obtain the best combination of methods in the case of private tutor selection.

D. Analysis

At this stage, the analysis process was carried out for each combination of *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* methods. The combination of these methods will be compared based on the comparison of the accuracy, ranking results, and preference values.

$$\text{Accuracy} = \frac{total\ valid\ data}{total\ data\ used} \times 100\% \quad (15)$$

$$\text{Ranking (\%)} = \frac{(total\ alternatives - ranking) + 1}{total\ alternatives} \times 100\% \quad (16)$$

$$\text{Preference average} = \frac{\sum preference}{total\ data\ used} \times 100\% \quad (17)$$

Accuracy indicated the level of accuracy of the recommendations given from each combination of methods to real data. The ranking shows the distance from the recommendation sequence resulting from each combination of methods to the real data. Meanwhile, preference shows the priority level obtained from each combination of methods to real data.

5. Results and Discussion

A. Result

The 6 choices of criteria that can be used in the weighting process in the case of private tutor selection in this research were education, experience, duration, and rating as benefit criteria, while cost and duration were cost criteria. From 118 student data, 34 students used the 6 criteria for the selection of private tutors including education, experience, cost, duration, rating, and distance. 30 students used 5 criteria in the selection of private tutors with 3 different combinations of criteria, namely 12 students used the criteria of education, experience, cost, duration, and rating. 7 students used the criteria of experience, cost, duration, rating, and distance. 11 students used the criteria of education, experience, duration, rating, and distance. 28 students used 4 criteria in the selection of private tutors with 4 different combinations of criteria, namely 10 students used the criteria of experience, cost, duration, and rating. 7 students used the criteria of cost, duration, rating, and distance. 7 students used the criteria of education, experience, cost, and distance. And 4 students used the criteria of education, experience, duration, and teaching rating. 26 students used 3 criteria in selecting private tutors with 4 different combinations of criteria, 11 students used the criteria of experience, duration, and rating. 5 students used the criteria of experience, cost, and distance. 4 students used the criteria of education, experience, and rating. And 6 students used the criteria of experience, cost, and rating. The weighting data was shown in Table 3, and the alternative data used in this case is shown in Table 4.

Table 3. Weighting Data

Student_Id	Weighting														
	Education/ Experience	Education/ Cost	Education/ Duration	Education/ Rating	Education/ Distance	Experience / Cost	Experience / Duration	Experience / Rating	Experience / Distance	Cost/ Duration	Cost/ Rating	Cost/ Distance	Duration/ Rating	Duration/ Distance	Rating / Distance
1	0.25	0.333	0.333	0.2	0.333	0.5	0.333	0.200	0.333	0.25	0.333	1	0.5	1	3
35	2	3	5	3		2	3	5		2	3		2		
47						1	3	3	0.5	1	3	1	5	0.25	0.143
54	2		3	3	1		3	5	1				0.333	0.333	0.5
65						1	1	1		2	3		2		
75										0.25	3	1	4	3	0.333
82	1	0.2			0.5	0.333			0.5			1			
89	2		3	1			3	0.5					0.25		
93							3	5					1		
104						0.333			2			3			
109	2			7				5							
113						1		1							

Table 4. Alternative Data

Teacher_ id	Education	Experience	Cost (IDR)	Duration (Minutes)	Teaching Rating	Distance (Km)
g_1	3	36	75000	60	5	7.1
g_2	3	24	75000	90	5	4
g_3	4	25	75000	60	4.5	8.1
g_4	4	36	75000	90	4	5
g_5	3	12	45000	60	4.7	4.3
g_6	3	48	50000	60	5	5
g_7	3	24	50000	60	4.5	7
g_8	3	50	75000	60	5	7
g_9	4	50	75000	60	4.6	7.6
g_10	3	12	75000	90	4	4
g_11	3	0	35000	60	0	4
g_12	3	45	75000	90	5	5.1
g_13	3	12	50000	60	4.3	5.2
g_14	1	0	40000	60	0	5
g_15	3	24	50000	60	4.5	5.2

Description:

- Assessment of educational criteria:
  1: University students
  2: Associate degree
  3: Bachelor’s degree
  4: Master’s degree
  5: Doctoral degree

a. The Weighting Process with *AHP* Method

1. Determine the pairwise comparison matrix

At this stage, a comparison was made between the selection of the criteria contained in private tutors with the Saaty Scale (1 to 9). The comparison of the selection of private tutors was shown in Table 5.

Table 5. Pairwise Comparison Matrix of Private Tutor Selection with 6 Criteria

Criteria	Education	Experience	Cost	Duration	Rating	Distance
Education	1	0.250	0.333	0.333	0.2	0.333
Experience	4	1	0.5	0.333	0.2	0.333
Cost	3	2	1	0.25	0.333	1
Duration	3	3	4	1	0.5	1
Rating	5	5	3	2	1	3
Distance	3	3	1	1	0.333	1
Total	19	14.256	9.836	4.916	2.566	6.666

2. Determine the priority weight scale

The new column row value matrix was obtained by dividing the initial row column value by the total of each initial column. The matrix of criteria values and priority weights for private tutor selection was shown in Table 6.

Table 6. Matrix of Criteria Scores and Priority Weights for Private Tutor Selection with 6 Criteria

Criteria	Education	Experience	Cost	Duration	Rating	Distance	Total	Priority
Education	0.053	0.018	0.034	0.068	0.078	0.050	0.300	0.050
Experience	0.210	0.070	0.051	0.068	0.078	0.050	0.527	0.088
Cost	0.158	0.140	0.102	0.051	0.130	0.150	0.731	0.122
Duration	0.158	0.211	0.407	0.203	0.195	0.150	1.324	0.221
Rating	0.263	0.351	0.305	0.407	0.390	0.450	2.166	0.361
Distance	0.158	0.211	0.102	0.203	0.130	0.150	0.954	0.159
Total	1	1	1	1	1	1	6	1

3. Determne the consistency ratio

After getting the weight of each criterion, the next step was to check the consistency ratio to find out whether the pairwise comparisons made were consistent or not. Determine the summation matrix of each row. This matrix was made by multiplying the priority weight values in Table 6 with the pairwise comparison matrix in Table 5. The calculation results was shown in Table 7.

Table 7. Matrix for the Sum of Each Row of Private Tutor Selection Criteria with 6 Criteria

Criteria	Education	Experience	Cost	Duration	Rating	Distance	Total
Education	0.050	0.022	0.041	0.073	0.072	0.053	0.311
Experience	0.200	0.088	0.061	0.073	0.072	0.053	0.547
Cost	0.150	0.176	0.122	0.055	0.120	0.159	0.782
Duration	0.150	0.264	0.487	0.221	0.180	0.159	1.461
Rating	0.250	0.439	0.366	0.441	0.361	0.477	2.333
Distance	0.150	0.264	0.122	0.221	0.120	0.159	1.035

This calculation was used to ensure that the value of the consistency ratio (CR) ≤ 0.1. The calculation of the consistency ratio was shown in Table 8.

Table 8. Consistency Ratio of Private Tutor Selection Criteria with 6 Criteria

Criteria	Total	Priority	Total = total/priority
Education	0.311	0.050	6.228
Experience	0.547	0.088	6.228
Cost	0.782	0.122	6.420
Duration	1.461	0.221	6.622
Rating	2.333	0.361	6.465
Distance	1.035	0.159	6.514
Total			38.477

$$\lambda \text{maks} = \frac{38.477}{6} = 6.413$$

$$\text{IR} = 1.24$$

$$CR = \frac{0.0031}{1.24} = 0.067$$

W = [0.05 ; 0.088 ; 0.122 ; 0.221 ; 0.361 ; 0.159]

b. Alternative Ranking

- *AHP-SAW*

1. Normalized

Identify criteria that have attributes that were benefit or cost, then normalized the matrix.

$$\text{r}_{11} = \frac{3}{MAX\ \{1; 3; 4\}} = 0.75$$

$$\text{r}_{12} = \frac{36}{MAX\ \{0; 12; 24; 25; 36; 45; 48; 50\}} = 0.72$$

$$\text{r}_{13} = \frac{MIN\ \{3500; 40000; 45000; 50000; 75000\}}{75000} = 0.467$$

$$\text{r}_{14} = \frac{60}{MAX\ \{60; 90\}} = 0.667$$

$$\text{r}_{15} = \frac{5}{MAX\ \{0; 4; 4.3; 4.5; 4.6; 4.7; 5\}} = 1$$

$$\text{r}_{16} = \frac{MIN\ \{4; 4.3; 5; 5.1; 5.2; 7; 7.1; 7.6; 8.1\}}{7.1} = 0.563$$

and so on, the normalization result of *SAW* was shown in Table 9.

Table 9. Normalization Results of SAW

Teacher_id	Education	Experience	Cost	Duration	Rating	Distance
g_1	0.750	0.720	0.467	0.667	1.000	0.563
g_2	0.750	0.480	0.467	1.000	1.000	1.000
g_3	1.000	0.500	0.467	0.667	0.900	0.494
g_4	1.000	0.720	0.467	1.000	0.800	0.800
g_5	0.750	0.240	0.778	0.667	0.940	0.930
g_6	0.750	0.960	0.700	0.667	1.000	0.800
g_7	0.750	0.480	0.700	0.667	0.900	0.571
g_8	0.750	1.000	0.467	0.667	1.000	0.571
g_9	1.000	1.000	0.467	0.667	0.920	0.526
g_10	0.750	0.240	0.467	1.000	0.800	1.000
g_11	0.750	0.000	1.000	0.667	0.000	1.000
g_12	0.750	0.900	0.467	1.000	1.000	0.784
g_13	0.750	0.240	0.700	0.667	0.860	0.769
g_14	0.250	0.000	0.875	0.667	0.000	0.800
g_15	0.750	0.480	0.700	0.667	0.900	0.769

2. V vector calculation and ranking results

The final results can be obtained by multiplying the priority weights of the results from the *AHP* method in Table 8 with the normalized matrix R using the SAW method in Table 9.

$V_1 = (0.05 \times 0.750) + (0.088 \times 0.720) + (0.122 \times 0.467) + (0.221 \times 0.667) + (0.361 \times 1.00) + (0.159 \times 0.563) = 0.755$

and so on, the ranking results with preference values for each alternative were obtained was shown in Table 10.

Table 10. Final Results of the AHP-SAW Method Combination

Teacher_id	Preference
g_1	0.755
g_2	0.877
g_3	0.701
g_4	0.806
g_5	0.787
g_6	0.842
g_7	0.728
g_8	0.781
g_9	0.757
g_10	0.784
g_11	0.465
g_12	0.880
g_13	0.723
g_14	0.393
g_15	0.759

The teacher who was recommended to use the *AHP-SAW* method was g_12 with a preference value of 0.880.

- *AHP-WP*

1. Normalized

Identify criteria that have attributes that are benefit or cost, then the vector S can be calculated.

$$S_1 = (3^{0.05})(36^{0.088})(75000^{-0.122})(60^{0.221})(5^{0.361})(7.1^{-0.159}) = 1.192$$

and so on, the calculation on vector S was shown in Table 11.

Table 11. Calculations on Vector S

Teacher_id	Education	Experience	Cost	Duration	Rating	Distance	Vector S
g_1	1.056	1.370	0.255	2.467	1.788	0.732	1.192
g_2	1.056	1.322	0.255	2.698	1.788	0.802	1.378
g_3	1.072	1.327	0.255	2.467	1.721	0.717	1.104
g_4	1.072	1.370	0.255	2.698	1.649	0.774	1.290
g_5	1.056	1.244	0.271	2.467	1.748	0.793	1.220
g_6	1.056	1.405	0.268	2.467	1.788	0.774	1.358
g_7	1.056	1.322	0.268	2.467	1.721	0.734	1.166
g_8	1.056	1.410	0.255	2.467	1.788	0.734	1.229
g_9	1.072	1.410	0.255	2.467	1.735	0.724	1.194
g_10	1.056	1.244	0.255	2.698	1.649	0.802	1.196
g_11	1.056	0.000	0.280	2.467	0.000	0.802	0.000
g_12	1.056	1.397	0.255	2.698	1.788	0.772	1.401
g_13	1.056	1.244	0.268	2.467	1.693	0.769	1.131
g_14	1.000	0.000	0.275	2.467	0.000	0.774	0.000
g_15	1.056	1.322	0.268	2.467	1.721	0.769	1.222

2. Ranking results

The value of the vector V to be used for ranking can be calculated.

$$V_1 = \frac{1.192}{16.080} = 0.074$$

and so on, the ranking results with preference values for each alternative were obtained was shown in Table 12.

Table 12. Ranking Results of the AHP-WP Method Combination

Teacher_id	Preference	Ranking
g_1	0.074	10
g_2	0.086	2
g_3	0.069	13
g_4	0.080	4
g_5	0.076	7
g_6	0.084	3
g_7	0.072	11
g_8	0.076	5
g_9	0.074	9
g_10	0.074	8
g_11	0.000	14
g_12	0.087	1
g_13	0.070	12
g_14	0.000	15
g_15	0.076	6

The teacher who was recommended to use the *AHP-WP* method was g_12 with a preference value of 0.087.

- *AHP-TOPSIS*

1. Normalized decision matrix

$X_1 = \sqrt{3^2 + 3^2 + 4^2 + 4^2 + 3^2 + 3^2 + 3^2 + 3^2 + 4^2 + 3^2 + 3^2 + 3^2 + 3^2 + 1^2 + 3^2} = 12.166$
$R_{1,1}$ = 3 / 12.166 = 0.247
$R_{1,2}$ = 3 / 12.166 = 0.247
$R_{1,3}$ = 4 / 12.166 = 0.329
$R_{1,4}$ = 4 / 1.166 = 0,329
$R_{1,5}$ = 3 / 12.166 = 0,247
$R_{1,6}$ = 3 / 12.166 = 0,247
$R_{1,7}$ = 3 / 12.166 = 0,247
$R_{1,8}$ = 3 / 12.166 = 0.247
$R_{1,9}$ = 4 / 12.166 = 0.329
$R_{1,10}$ = 3 / 12.166 = 0.247
$R_{1,11}$ = 3 / 12.166 = 0.247

$R_{1,12}$ = 3 / 12.166 = 0.247
$R_{1,13}$ = 3 / 12.166 = 0.247
$R_{1,14}$ = 1 / 12.166 = 0.082
$R_{1,15}$ = 3 / 12.166 = 0.247

and so on, the results of normalization R were obtained was shown in Table 13.

Table 13. TOPSIS Normalization Results

Teacher _id	Education	Experience	Cost	Duration	Rating	Distance
g_1	0.247	0.297	0.307	0.224	0.299	0.320
g_2	0.247	0.198	0.307	0.335	0.299	0.180
g_3	0.329	0.206	0.307	0.224	0.269	0.365
g_4	0.329	0.297	0.307	0.335	0.239	0.225
g_5	0.247	0.099	0.184	0.224	0.281	0.194
g_6	0.247	0.396	0.204	0.224	0.299	0.225
g_7	0.247	0.198	0.204	0.224	0.269	0.315
g_8	0.247	0.412	0.307	0.224	0.299	0.315
g_9	0.329	0.412	0.307	0.224	0.275	0.342
g_10	0.247	0.099	0.307	0.335	0.239	0.180
g_11	0.247	0.000	0.143	0.224	0.000	0.180
g_12	0.247	0.371	0.307	0.335	0.299	0.230
g_13	0.247	0.099	0.204	0.224	0.257	0.234
g_14	0.082	0.000	0.164	0.224	0.000	0.225
g_15	0.247	0.198	0.204	0.224	0.269	0.234

2. The normalized decision matrix was weighted Y, multiplying the normalized results R in Table 4 with the priority weights in Table 14.

Table 14. Weighted Normalized Results Y

Teacher _id	Education	Experience	Cost	Duration	Rating	Distance
g_1	0.012	0.026	0.037	0.049	0.108	0.051
g_2	0.012	0.017	0.037	0.074	0.108	0.029
g_3	0.016	0.018	0.037	0.049	0.097	0.058
g_4	0.016	0.026	0.037	0.074	0.086	0.036
g_5	0.012	0.009	0.022	0.049	0.101	0.031
g_6	0.012	0.035	0.025	0.049	0.108	0.036
g_7	0.012	0.017	0.025	0.049	0.097	0.050
g_8	0.012	0.036	0.037	0.049	0.108	0.050
g_9	0.016	0.036	0.037	0.049	0.099	0.054
g_10	0.012	0.009	0.037	0.074	0.086	0.029
g_11	0.012	0.000	0.017	0.049	0.000	0.029
g_12	0.012	0.033	0.037	0.074	0.108	0.036
g_13	0.012	0.009	0.025	0.049	0.093	0.037
g_14	0.004	0.000	0.020	0.049	0.000	0.036
g_15	0.012	0.017	0.025	0.049	0.097	0.037

3. Positive Ideal Solution Matrix (A^+)

Identify criteria that have attributes that were benefit or cost, then calculate A^+.

y_1^+ = max {0.012;0.012;0.016;0.016;0.012;0.012;0.012;0.012;0.016;0.012; 0.01;0.012;0.012;0.004;0.012} = 0.116
y_2^+ = max {0.026;0.017;0.018;0.026;0.009;0.035;0.017;0.036;0.036;0.009; 0.000;0.033;0.009;0.000;0.017} = 0.036
y_3^+ = min {0.037;0.037;0.037;0.037;0.022;0.025;0.025;0.037;0.037;0.037; 0.017;0.037;0.025;0.020;0.025} = 0.017
y_4^+ = max {0.049;0.074;0.049;0.074;0.049;0.049;0.049;0.049;0.049;0.074; 0.049;0.074;0.049;0.049;0.049} = 0.074
y_5^+ = max {0.108;0.108;0.097;0.086;0.101;0.108;0.097;0.108;0.099;0.086; 0.000;0.108;0.093;0.000;0.097} = 0.108
y_6^+ = min {0.051;0.029;0.058;0.036;0.031;0.036;0.050;0.050;0.054;0.029; 0.029;0.036;0.037;0.036;0.037} = 0.029
A^+ = {0.116;0.036;0.017;0.074;0.108;0.029}

4. Negative Ideal Solution Matrix (A^-)

Identify criteria that have attributes that were benefit or cost, then calculate A^-.

y_1^- = min {0.012;0.012;0.016;0.016;0.012;0.012;0.012;0.012;0.016;0.012; 0.01;0.012;0.012;0.004;0.012} = 0.004

y_2^- = min {0.026;0.017;0.018;0.026;0.009;0.035;0.017;0.036;0.036;0.009; 0.000;0.033;0.009;0.000;0.017} = 0.000
y_3^- = max {0.037;0.037;0.037;0.037;0.022;0.025;0.025;0.037;0.037;0.037; 0.017;0.037;0.025;0.020; 0.025} = 0.037
y_4^- = min {0.049;0.074;0.049;0.074;0.049;0.049;0.049;0.049;0.049;0.074; 0.049;0.074;0.049;0.049;0.049} = 0.049
y_5^- = min {0.108;0.108;0.097;0.086;0.101;0.108;0.097;0.108;0.099;0.086; 0.000;0.108;0.093;0.000;0.097} = 0.000
y_6^- = max {0.051;0.029;0.058;0.036;0.031;0.036;0.050;0.050;0.054;0.029; 0.029;0.036;0.037;0.036;0.037} = 0.058
A^- = {0.004;0.000;0.037;0.049;0.000;0.058}

5. The distance between the weighted value of each alternative to the positive ideal solution Si^+, multiplying the normalized weighted result Y in Table 4 with the value A^+.

$$D_{1+} = \sqrt{(0.116-0.012)^2+(0.036-0.026)^2+(0.017-0.037)^2+(0.074-0.049)^2+(0.108-0.108)^2+(0.029-0.051)^2} = 0.040$$

and so on, the results was shown in Table 15.

Table 15. Positive Ideal Solutions Si+

Teacher_id	D+
g_1	0.040
g_2	0.028
g_3	0.048
g_4	0.032
g_5	0.038
g_6	0.027
g_7	0.040
g_8	0.039
g_9	0.042
g_10	0.040
g_11	0.117
g_12	0.022
g_13	0.042
g_14	0.117
g_15	0.035

6. The distance between the weighted value of each alternative to the negative ideal solution Si^- multiplying the weighted results normalized Y in Table 4 by the value of A^-.

$$D_{1-} = \sqrt{(0.004-0.012)^2+(0.000-0.026)^2+(0.037-0.037)^2+(0.049-0.049)^2+(0.000-0.108)^2+(0.058-0.051)^2} = 0.112$$

and so on, the results was shown in Table 16.

Table 16. Si-Negative Ideal Solution

Teacher_id	D-
g_1	0.112
g_2	0.116
g_3	0.100
g_4	0.097
g_5	0.107
g_6	0.117
g_7	0.100
g_8	0.114
g_9	0.106
g_10	0.095
g_11	0.036
g_12	0.118
g_13	0.097
g_14	0.028
g_15	0.102

7. Ranking results

$$V_1 = \frac{0.112}{0.040+0.112} = 0.735$$

and so on, the ranking results with preference values for each alternative were obtained was shown in Table 17.

Table 17. Ranking Results using AHP-TOPSIS Method Combination

Teacher_id	Preference	Ranking
g_1	0.735	8
g_2	0.807	3
g_3	0.675	13
g_4	0.752	4
g_5	0.737	7
g_6	0.811	2
g_7	0.714	10
g_8	0.748	5
g_9	0.718	9
g_10	0.702	11
g_11	0.238	14
g_12	0.842	1
g_13	0.699	12
g_14	0.194	15
g_15	0.744	6

The teacher who was recommended to use the *AHP-TOPSIS* method was g_12 with a preference value of 0.842.

From these calculations, *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* provide recommendations for teacher names that were the same as real data from decisions made in private tutoring places. Thus, the accuracy and ranking values obtained from the three methods were good, but the results of the preference values are different. *AHP-SAW* produced a preference value of 0.880, *AHP-WP* of 0.087, and *AHP-TOPSIS* of 0.842. The comparison of the preferences of the three combinations of methods showed that the AHP-SAW method gave higher preference results than the *AHP-WP* and *AHP-TOPSIS*.

This research used 118 respondents consisting of parents and students. The results of the accuracy, ranking, and preference for each combination of methods were shown in Table 18.

Table 18. The Results of the Accuracy, Ranking, and Preference

		ACCURACY				RANKING			PREFERENCE		
student_id	**CR AHP**	**AHP-SAW**	**AHP-WP**	**AHP-TOPSIS**	**Real Data**	**AHP-SAW**	**AHP-WP**	**AHP-TOPSIS**	**AHP-SAW**	**AHP-WP**	**AHP-TOPSIS**
1	0.067	g_12	g_12	g_12	g_12	100%	100%	100%	0.88	0.087	0.842
2	0.080	g_9	g_9	g_9	g_9	100%	100%	100%	0.846	0.091	0.821
3	0.036	g_9	g_9	g_9	g_9	100%	100%	100%	0.846	0.091	0.826
4	0.049	g_9	g_9	g_9	g_9	100%	100%	100%	0.848	0.09	0.807
5	0.072	g_12	g_12	g_12	g_12	100%	100%	100%	0.887	0.087	0.857
... 118	0.012	g_8	g_6	g_6	g_14	7%	7%	7%			
Average		**88.14%**	**68.64%**	**66.95%**		**91%**	**88%**	**89%**	**0.771**	**0.073**	**0.564**

Table description:

: Decision recommendations resulting from a combination of different or invalid methods with real results of decisions in private tutoring.

In the *AHP-SAW* method, there were 14 out of 118 invalid decision recommendation data. So the combination of the *AHP-SAW* method has an accuracy rate of 88.14%. In the *AHP-WP* method, there are 37 invalid decision recommendations. So the combination of the *AHP-WP* method has an accuracy rate of 68.64 %. Meanwhile, in the *AHP-TOPSIS* method, there are 39 invalid decision recommendations, so the accuracy rate of the *AHP-TOPSIS* method was 66.95%. The average value of ranking with the *AHP-SAW* method of 91%, *AHP-WP* of 88%, and *AHP-TOPSIS* of 89%. In addition, the three combinations were also compared based on preference values. The average preference value obtained from the *AHP-SAW* method of 0.771, *AHP-WP* of 0.073, and *AHP-TOPSIS* of 0.564.

B. Discussion

The comparison of each combination of *AHP-SAW*, *AHP-WP*, and *AHP-TOPSIS* methods based on accuracy, rating, and preference gives different results. The combination of the *AHP-SAW* method showed better results than *the AHP-WP* and *AHP-TOPSIS* methods. In addition to the effect of the total criteria and alternatives used, this difference in results was also caused by different normalization methods from the *SAW*, *WP*, and *TOPSIS* methods at the ranking stage. The *SAW* method required the process of normalize the decision matrix to a scale, which can be compared with all the different alternative ratings. The *WP* method used multiplication to relate rating criteria. The rating of each criterion must be raised to the power of the weight of the relevant criteria. While the *TOPSIS* method used the performance rating of each alternative on each of the previously normalized criteria. The finding that the difference in the results obtained was caused by normalization was relevant to the research conducted by Nugraha and Mahendra (2020) [12].

The *AHP-SAW* method gave better results because prospective service users were given the freedom to choose and compare alternative teachers available based on their wishes and needs. In ranking to determine the recommended teacher in the *SAW* method, compare each criterion with each alternative. Each benefit criterion will be compared with the largest value in that criterion from all available alternatives. As for the cost criteria, the smallest value of the criteria will be sought first from all alternatives and then compared for each criterion [48-50]. So that the alternative that has the largest benefit criterion value and the smallest cost criterion value will have a greater value and was more recommended based on the importance of the weight on each criterion. The ranking process and preferences were obtained from the addition of the normalized matrix multiplication with the weights generated from the *AHP* method. This can give results that tend to be higher than the combination of other methods.

It was different in the *AHP-WP* method which used the weight value of each criterion obtained from the *AHP* method to be a positive rank value for the benefit criteria, and a negative rank for the cost criterion, then the results of each criterion in the alternative were multiplied and form a vector matrix S. To get the results ranking and preference, where the value of each alternative in the matrix then compared with the sum of the overall alternative values [51-55]. In use this method, it was also found that if there were > 1 criteria in the alternative with a value of 0, then when entering the ranking process with *WP* the value of the alternative became 0 and was in the last ranking. That was because the normalization results of each criterion in the alternative were multiplied, so if one of the criteria in the alternative of 0 then the preference value becomes 0. If this method was applied in the case of selecting private tutors, then new teachers who seem to have no teaching experience or rating because they have never taught at the tutoring site, will certainly not be recommended or were in the lowest ranking. So, this method was not appropriate when used in the case of private tutor selection. Unlike the case with *AHP-TOPSIS* when it enters the ranking process. Even though there were criteria for several alternatives that were provided with a value of 0, the alternative still has a preference value and was not always in the last ranking. This depends on the level of need for the criteria that have been inputted through the weighting process [31]. However, the comparison of positive and negative ideal solutions tends to give smaller results than the *AHP-SAW* method.

6. Conclusions

Comparison based on the value of accuracy, ranking, and preference of 118 recommended data from the calculations of the three combinations of methods, it can be seen that the combination of the *AHP-SAW* method has better results than the *AHP-WP* and *AHP TOPSIS* methods. That was because the matrix that has been normalizing in the *SAW* method was based on the highest benefit value and the lowest cost value, then multiplied by the weights generated in the *AHP* method and added together, thus giving results that tend to be higher than other combinations of methods.

In the weighting process with the *AHP* method in this study, the researcher calculated the consistency ratio to measure the level of consistency in providing a scale on the pairwise comparison matrix, if the CR value > 0.1 then the user must re-enter the scale on the comparison matrix. It was hoped that further research will use other methods to optimize and compare the weighting results obtained so that the right method was found that can make the weighing process more efficient and with a higher level of accuracy for the case of private tutor selection.

This research only compared each combination based on the results of ranking and preference values, the level of accuracy of the suitability of the results found in the field in the case of private tutor selection. It was hoped that further research can compare the three combinations of methods with other methods, such as the algorithm performance or others.

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Authors' Profiles

Ni Komang Yanti Suartini is a master's degree student in the Computer Science Department from *Universitas Pendidikan Ganesha*. Her research interest area is Decision Support Systems.

Dewa Gede Hendra Divayana is an Associate Professor in the field of Informatics Education at the Department of Informatics Education, Faculty of Technical and Vocational, *Universitas Pendidikan Ganesha*. He received his Doctoral Degree in Measurement and Evaluation in Education from *Universitas Negeri Jakarta*. His research interest areas are Evaluation in Education, Decision Support Systems in Education, Informatics in Education, and Artificial Intelligence in Education.

Luh Joni Erawati Dewi is an Associate Professor in Informatics Engineering and the Computer Science postgraduate program, at *Universitas Pendidikan Ganesha*. She received her Doctoral Degree in Measurement and Evaluation in Education from *Universitas Negeri Jakarta*. Her research interest areas are the development of information systems and informatics in education.

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