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Comparative analysis of the sensitivity test of the SAW and WP methods in scholarship selection

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Abstract

Decision-makers frequently use the MADM (Multiple Attribute Decision Making) method to assist in solving decision-making issues. This approach can use a variety of algorithms, including Simple Additive Weighting (SAW) and Weighted Product (WP). The challenge in this research is determining which of the SAW and WP approaches is more pertinent or acceptable for solving scenarios involving scholarship recipient selection. Five factors were taken into consideration when deciding who would receive a scholarship: academic achievement index (GPA), parents' income, past accomplishments, participation in student organizations, and the number of parents' dependents. A sensitivity test, which involves altering the weight of each test method's criterion and then comparing the percentage change between the two ways, is one method that can be used to gauge the effectiveness of the MADM method. The SAW method implementation results show that alternative nine (MHS9) has the highest preference value, which is 0.95. The WP method implementation results show that alternative nine (MHS9) has the highest preference value, which is 0.12. The total change in the findings of the sensitivity test for the SAW method is 7.64%, compared to 2.06% for the WP method. Thus, it can be inferred that the SAW approach is thought to be pertinent for addressing the issue of choosing scholarship applicants.

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1. Introduction

One of the technologies with the quickest growth is information technology. Because of this, businesses or government entities must be very cunning in utilizing the requirement for reliable information systems [1][2]. The method used to collect data, process data, and create knowledge that may be utilized as a guide to support strategic decision-making operations [3][4].

Decision makers frequently employ decision support systems, a methodical technique, to aid in the resolution of decision-making issues [5][6][7]. Lack of knowledge about the right decision-making process, which leads to poor decisions, is a problem that frequently arises in the selection of the DSS technique to be utilized in solving difficulties posed by a decision maker [8][5][9]. In addition, a decision maker faces a unique challenge in the absence of a comparison tool for the outcomes of judgments reached by mathematical calculations [10][11].

Numerous scholarships are available in educational institutions, particularly universities, for both students from disadvantaged backgrounds and those who demonstrate academic excellence. The Directorate General of Higher Education of the Ministry of National Education is responsible for allocating funding to grant scholarships to deserving students as well as those who are unable to afford their education due to financial constraints. In order to implement the scholarship program in line with the 3T principles, which stand for right on target, right amount, and right time. Making the proper choice enables the scholarship's implementation aim to be met by creating the 3T principles [12].

It may be determined from prior study that used the SAW and WP methods for assessing employee performance at the PT. Pelabuhan Indonesia II (Persero) Bengkulu branch that the SAW method has a total change of 0% whereas the WP approach is 0.000256% based on the findings of the sensitivity test [13]. Different results were obtained in the decision support system for selecting extracurricular activities [14], evaluation of cashier performance [15], the process of determining internal information media articles at PT Pos Indonesia (Persero) [16], determining the location of dissemination of promotional media [17], selecting model teachers at SMA Negeri 4 Sarolangun [18], determining the location of agricultural land for tangerang cultivation [19], determining location points for wireless internet repeaters [20], selecting student admissions at MAN 2 Jambi City [21], selection of laptops [22], selection of student creativity program proposals [23], determining the best employees at the department of horticulture and plantation crops [24], determination of the location of the automatic teller machine [25], lecturer selection [26], selection of suppliers of production raw materials [27], determination of diakonia recipients [28] based on sensitivity tests shows that SAW method is considered relevant in solving problems [29]–[32].

Given the issues raised above, there must be a method that can offer suggestions when comparing the ranking results of the SAW and WP methods. This method should perform a sensitivity test to look for changes in the ranking results of the two MADM methods. The more sensitive the value obtained from each ranking change in each MADM method, the more likely it will be chosen. This approach can assist scholarship winners make decisions since it can identify an ideal answer without being constrained by a particular situation. In order to determine whether approach is applicable for the situation of scholarship recipients based on the test findings of the two ways, the authors of this study ran a sensitivity test on the SAW (Simple Additive Weighting) and WP (Weighted Product) methods.

2. Methods

As shown in the Figure 1, the flow of research conducted consists of three main stages, including: determination of criteria and weights, the application of the simple additive weighting (SAW) method and the weighted product (WP) method, and test of sensitivity of each method [33][34][35].

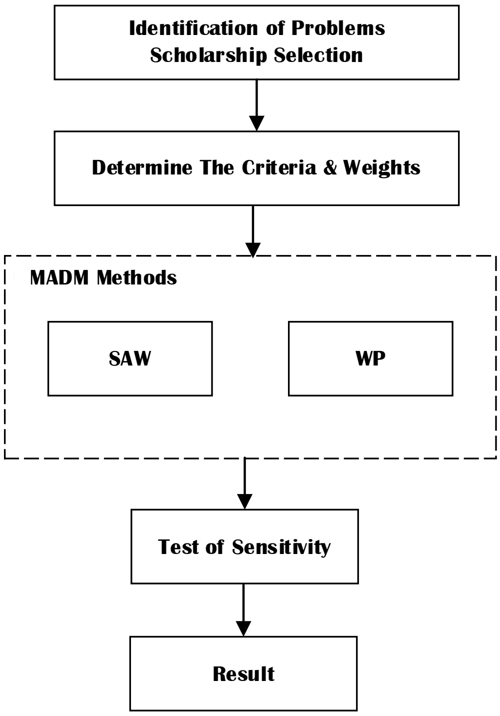

Figure 1. The Flow of Research of Sensitivity Test using Simple Additive Weighting (SAW) Method and Weighted Product (WP) Method for Scholarship Selection

2.1 Simple Additive Weighting (SAW)

The weighted sum method is another name for the Simple Additive Weighting (SAW) technique. Finding the weighted total of the performance ratings for each alternative across all attributes is the fundamental tenet of the SAW technique [36][37][38]. The choice matrix (X) must be normalized for the SAW technique so that it may be compared to all other available alternative ratings on the same scale [3][39].

The normalizing procedure follows the following formula:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\underset{i}{\text{Max}}\, x_{ij}} & \text{if } \mathbf{j} \text{ is the benefit attribute} \\ \dfrac{\underset{i}{\text{Min}}\, x_{ij}}{x_{ij}} & \text{if } \mathbf{j} \text{ is the cost attribute} \end{cases} \quad (1)$$

Where r_{ij} is the normalized performance rating of alternative A_i on attribute C_j ; i=1,2,...,m and j=1,2,...,n.

The preference value for each alternative (V_i) is given as follows:

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \quad (2)$$

A larger V_i value indicates that alternative A_i is more selected.

Steps for finishing the MADM method using the SAW technique:

a. Identify the standards used as a guide for making decisions.
b. Find out how suitable each choice is for each condition.

c. Create a decision matrix based on the criteria, normalize the matrix using the equation modified for the attribute type, and then obtain the normalized matrix R.
d. The normalized matrix R is multiplied by the weight vector in such a way that the total is obtained as the final result, and the biggest value is chosen as the best choice as a solution.

2.2 Weighted Product (WP)

The WP approach multiplies the attribute ratings to connect them, and each attribute's rating must be raised to the power of the weight of the attribute [40][41]. It follows the same steps as normalization. This method is more effective because the calculation takes less time [3].
The WP approach has the following stages to be followed:

a. Establish the criteria: specifically, C_i and the characteristics of each criterion that will be utilized as a guide in making decisions.
b. Establish a decision matrix and determine the appropriateness rating, i.e. the suitability rating of each choice on each criterion.
c. Make weights uniform.
The normalized weight is the sum of the weights assigned to each criterion. The entire weight must have the following value:

$$W_j = \frac{w_i}{\sum w_j} \tag{3}$$

d. Multiply all the criteria for an option with the weight as a positive exponent for the benefit criterion and the weight as a negative exponent for the cost criterion to find the value of the vector S. the following formula is used to determine the preference value for alternative A_i:

$$S_i = \prod_{j=1}^{n} X_{i_j}^{w_j} \tag{4}$$

e. Establishes the vector V's value, or the ranking-relevant value. Each alternative's relative preference value can be determined by:

$$V_{jn} = \frac{S_i}{\sum S_i} \tag{5}$$

f. As the last step, rank the vector V's value while also drawing conclusions.

2.3 Test of Sensitivity

This sensitivity test was conducted to determine whether approach is more sensitive in a case in terms of ranking changes in each method by comparing the results of the methods used to solve MADM problems [42][20]. Users will find it simpler to select the optimal technique with the sensitivity test procedure included into the system, which will also offer a suitable answer for multi-attribute decision making (MADM) instances when utilizing the right approach. There are numerous steps that can be taken to determine the degree of sensitivity (S_j), including [43][44][45]:

a. Determine W_j = 1 for all attribute weights (initial weight).
b. While maintaining the same weights for the other criteria, change the weight of one criterion by increasing the weight value by 0.5 to 1.
c. Form the weight values so that w = 1 to normalize the attribute weights.
d. Next, determine the percentage change in ranking by comparing the highest value obtained from each computation to the initial weight conditions.

3. Results and Discussion

To decide who would be eligible for the scholarship, this study tested the sensitivity of the Weighted Product approach versus the Simple Additive Weighting method. The assessment criteria must be chosen in order to solve the problem because they will eventually be calculated using both approaches. Table 1 lists the criteria and the weights assigned to each in this study. There are five criteria that become variables in this case study, including scores on the academic achievement index (GPA), parents' earnings, things that have been accomplished, student organizations were followed, amount of parents' dependent children. All criteria are classified as benefits. Each criterion is given an initial weight which, when added together, is worth 1.

Table 1.
Criteria Data of Scholarship Selection

Code	Criteria Name	Criteria Type	Criteria Weight
C1	Scores on the Academic Achievement Index (GPA)	Benefits	0.26
C2	Parents' earnings	Benefits	0.23
C3	Things that have been accomplished	Benefits	0.15
C4	Student organizations were followed	Benefits	0.14
C5	Amount of parents' dependent children	Benefits	0.22

The following stage assigns a weight value to each criterion in order to establish its importance. The scale for determining the value's weight ranges from 0 to 1. The information needed to determine each criterion's relative value is shown in Table 2.

Table 2.
Criteria Importance Rating Data

Criteria Name	Criteria Scale	Criteria Weight
Scores on the Academic Achievement Index (GPA)	GPA <= 2.75	0
	2.75 < GPA <= 3.00	0.25
	3.00 < GPA <= 3.25	0.5
	3.25 < GPA <= 3.50	0.75
	GPA > 3.50	1
Parents' earnings	Salary <= 1 million	1
	1 million < Salary <= 5 million	0.75
	5 million < Salary <= 10 million	0.5
	Salary > 10 million	0.25
Things that have been accomplished	Yes	1
	No	0.5
Student organizations were followed	Yes	1
	No	0.5
Amount of parents' dependent children	1 child	0
	Two children	0.25
	3 children	0.5
	4 children	0.75
	>= 5 children	1

In the first criterion there are five criteria scales, if the GPA value is higher then the weight is greater. The second criterion will get a high weight if the criteria scale is small. The third and fourth criteria each have two criterion scales. The fifth criterion will get low weight if the scale is small. Furthermore, an evaluation of compatibility for each alternative on each criterion is carried out and a choice matrix is generated, as shown in table 4, based on the criteria data and the importance degree of each criterion. Table 3 is the initial data that we will process. There are 12 alternatives as test data samples. The test data will then be converted based on the criteria scale that has been made.

Table 3.
Alternative Value Data

Alternative	C1	C2	C3	C4	C5
MHS1	3.53	3000000	Yes	No	3
MHS2	3.41	4000000	No	No	6
MHS3	3.31	7000000	No	No	3
MHS4	3.13	4000000	No	No	5
MHS5	3.65	5000000	No	Yes	2
MHS6	3.96	2500000	Yes	No	2
MHS7	3.42	2500000	Yes	Yes	2

Alternative	C1	C2	C3	C4	C5
MHS8	3.88	11000000	Yes	No	3
MHS9	3.56	3000000	Yes	Yes	4
MHS10	3.69	2000000	Yes	Yes	2
MHS11	3.33	5000000	No	Yes	3
MHS12	3.03	12000000	No	No	1

The results of the conversion of each criterion and sub-criteria can be seen in Table 4.

Table 4.
Alternative Compatibility Rating Against Criteria

Alternative	C1	C2	C3	C4	C5
MHS1	1	0.75	1	0.5	0.5
MHS2	0.75	0.75	0.5	0.5	1
MHS3	0.75	0.50	0.5	0.5	0.5
MHS4	0.5	0.75	0.5	0.5	1
MHS5	1	0.75	0.5	1	0.25
MHS6	1	0.75	1	0.5	0.25
MHS7	0.75	0.75	1	1	0.25
MHS8	1	0.25	1	0.5	0.5
MHS9	1	0.75	1	1	0.75
MHS10	1	0.75	1	1	0.25
MHS11	0.75	0.75	0.5	1	0.5
MHS12	0.5	0.25	0.5	0.5	0

The Simple Additive Weighting and Weighted Product procedures will be used to calculate the data from the outcomes of the aforementioned compatibility rating.

3.1. Results of Simple Additive Weighting Method

The normalization of the matrix completes the SAW method's calculation for choosing the first scholarship recipient. Determine the highest value of all choices for matrix normalization if the criterion is an advantage, and the lowest value of all alternatives if the criterion is a cost. For example in MHS1 the normalization process is shown as follows:

$$r_{11} = \frac{1}{\max\{1; 0.75; 0.75; 0.5; 1; 1; 0.75; 1; 1; 1; 0.75; 0.5\}} = \frac{1}{1} = 1$$

$$r_{21} = \frac{1}{\max\{1; 1; 0.67; 1; 1; 1; 1; 0.33; 1; 1; 1; 0.33\}} = \frac{1}{1} = 1$$

$$r_{31} = \frac{1}{\max\{1; 0.5; 0.5; 0.5; 0.5; 1; 1; 1; 1; 1; 0.5; 0.5\}} = \frac{1}{1} = 1$$

$$r_{41} = \frac{0.5}{\max\{0.5; 0.5; 0.5; 0.5; 1; 0.5; 1; 0.5; 1; 1; 1; 0.5\}} = \frac{0.5}{1} = 0.5$$

$$r_{51} = \frac{0.5}{\max\{0.5; 1; 0.5; 1; 0.25; 0.25; 0.25; 0.5; 0.75; 0.25; 0.5; 0\}} = \frac{0.5}{1} = 0.5$$

Table 5 displays the outcomes of computing the matrix normalization for each condition.

Table 5
Matrix Normalization Results

Alternative	C1	C2	C3	C4	C5
MHS1	1	1	1	0.5	0.5
MHS2	0.75	1	0.5	0.5	1
MHS3	0.75	0.67	0.5	0.5	0.5

Alternative	C1	C2	C3	C4	C5
MHS4	0.5	1	0.5	0.5	1
MHS5	1	1	0.5	1	0.25
MHS6	1	1	1	0.5	0.25
MHS7	0.75	1	1	1	0.25
MHS8	1	0.33	1	0.5	0.5
MHS9	1	1	1	1	0.75
MHS10	1	1	1	1	0.25
MHS11	0.75	1	0.5	1	0.5
MHS12	0.5	0.33	0.5	0.5	0

The criteria weight is multiplied by each row of the normalized value matrix to arrive at the preference value for each choice. As an example of the result of calculating the preference value from MHS1 as follows:

$$V_1 = (0.26)(1) + (0.23)(1) + (0.15)(1) + (0.14)(0.5) + (0.22)(0.5)$$
$$= 0.26 + 0.23 + 0.15 + 0.07 + 0.11 = 0.82$$

The outcomes are shown in Table 6.

Table 6.
Preference/Ranking Value Results

Alternative	C1	C2	C3	C4	C5	Total	Rank
MHS1	0.260	0.230	0.150	0.07	0.110	0.820	3
MHS2	0.195	0.230	0.075	0.07	0.220	0.790	4
MHS3	0.195	0.153	0.075	0.07	0.110	0.603	11
MHS4	0.130	0.230	0.075	0.07	0.220	0.725	9
MHS5	0.260	0.230	0.075	0.14	0.055	0.760	7
MHS6	0.260	0.230	0.150	0.07	0.055	0.765	6
MHS7	0.195	0.230	0.150	0.14	0.055	0.770	5
MHS8	0.260	0.077	0.150	0.07	0.110	0.667	10
MHS9	0.260	0.230	0.150	0.14	0.165	0.945	1
MHS10	0.260	0.230	0.150	0.14	0.055	0.835	2
MHS11	0.195	0.230	0.075	0.14	0.110	0.750	8
MHS12	0.130	0.077	0.075	0.07	0	0.352	12

According to the SAW method's calculation results, the MHS9 alternative code has a preference value of 0.945. The alternative sequences MHS9, MHS10, MHS1, MHS2, MHS7, MHS6, MHS5, MHS11, MHS4, MHS8, MHS3, and MHS12 have preference values ranging from high to low.

3.2. Results of Weighted Product Method

Determine the normalization of the weights by comparing the weights of each criterion to the total weights as the last step in utilizing the WP technique to choose the first scholarship applicant as shown table 7 for the results. For example in MHS1 the weight normalization process is shown as follows:

$$W_{11} = 1^{0.26} = 1$$
$$W_{21} = 0.75^{0.23} = 0.936$$
$$W_{31} = 1^{0.15} = 1$$
$$W_{41} = 0.5^{0.14} = 0.908$$
$$W_{51} = 0.5^{0.22} = 0.859$$

Table 7
Weight Normalization Results

Alternative	C1	C2	C3	C4	C5
MHS1	1	0.936	1	0.908	0.859
MHS2	0.928	0.936	0.901	0.908	1
MHS3	0.928	0.853	0.901	0.908	0.859
MHS4	0.835	0.936	0.901	0.908	1

MHS5	1	0.936	0.901	1	0.737
MHS6	1	0.936	1	0.908	0.737
MHS7	0.928	0.936	1	1	0.737
MHS8	1	0.727	1	0.908	0.859
MHS9	1	0.936	1	1	0.939
MHS10	1	0.936	1	1	0.737
MHS11	0.928	0.936	0.901	1	0.859
MHS12	0.835	0.727	0.901	0.908	0

Then, multiply the rank results of the value of each characteristic by normalizing the weight of each criterion to determine the value of S for each choice. Use a positive rank for assessing in table 8 the value of S if the criterion is an advantage, and a negative rank when the criterion is a cost. The total of the S values for alternatives 1 through 12 is 7.330

Table 8.
Results Grade S

Alternative	S
MHS1	0.729
MHS2	0.710
MHS3	0.556
MHS4	0.639
MHS5	0.622
MHS6	0.626
MHS7	0.640
MHS8	0.566
MHS9	0.879
MHS10	0.690
MHS11	0.672
MHS12	0
Total	**7.330**

The preference vector V value for each alternative is then calculated after the S value has been obtained, in table 9, namely by dividing the S value of each alternative by the sum of S values for all alternatives .

Table 9.
Result Value V

Alternative	V	Rank
MHS1	0.099	2
MHS2	0.097	3
MHS3	0.076	11
MHS4	0.087	7
MHS5	0.085	9
MHS6	0.085	8
MHS7	0.087	6
MHS8	0.077	10
MHS9	0.120	1
MHS10	0.094	4
MHS11	0.092	5
MHS12	0	12

The MHS9 alternative code has a preference value of 0.120, according to the WP method's calculating results. The alternative sequences MHS9, MHS1, MHS2, MHS10, MHS11, MHS7, MHS4, MHS6, MHS5, MHS8, MHS3, and MHS12 have preference values ranging from high to low.

3.3. Results of Test Sensitivity

The next step is to conduct an analysis by running a sensitivity test based on the findings from the two decision method calculations. To determine how sensitive a method is if it is used to solve a specific situation, a sensitivity test is conducted. A method is increasingly used if it has a high sensitivity value or is more sensitive than any change in ranking.

Table 10 displays the outcomes of calculations using the weights (0.26, 0.23, 0.15, 0.14, 0.22) for both techniques.

Table 10.
Calculation Results of the Two MADM Methods

Alternative	SAW	WP
MHS1	0.820	0.099
MHS2	0.790	0.097
MHS3	0.603	0.076
MHS4	0.725	0.087
MHS5	0.760	0.085
MHS6	0.765	0.085
MHS7	0.770	0.087
MHS8	0.667	0.077
MHS9	0.945	0.120
MHS10	0.835	0.094
MHS11	0.750	0.092
MHS12	0.352	0

Change the first criterion's weight by 0.5, changing the weights used to (0.76; 0.23; 0.15; 0.14; 0.22), and obtaining the results of the first sensitivity test. To acquire the results of the second sensitivity test as shown on table 11, make further adjustments by raising the weight of the first criterion by 1, making the weights used become (1.26, 0.23, 0.15, 0.14, 0.22).

Table 11.
Sensitivity Test Results in The First Criterion

	Sensitivity Test 1		Sensitivity Test 2	
Alternative	SAW	WP	SAW	WP
MHS1	1.32	0.107	1.820	0.115
MHS2	1.165	0.091	1.540	0.084
MHS3	0.978	0.071	1.353	0.065
MHS4	0.975	0.067	1.225	0.050
MHS5	1.26	0.091	1.760	0.098
MHS6	1.265	0.092	1.765	0.098
MHS7	1.145	0.082	1.520	0.075
MHS8	1.167	0.083	1.667	0.089
MHS9	1.445	0.129	1.945	0.138
MHS10	1.335	0.102	1.835	0.108
MHS11	1.125	0.086	1.500	0.079
MHS12	0.602	0	0.852	0

By following the same procedures but raising each criterion's weight by one, with a range between 0.5 and 1. Table 12 displays a summary of the sensitivity test outcomes.

Table 12.
Summary of Sensitivity Test Results

Criteria	SAW	WP	Value Change	
			SAW	WP
1st Value	0.945	0.120	0	0
C1 + 0.5	1.445	0.129	0.529	0.078
C1 + 1	1.945	0.138	1.058	0.151
C2 + 0.5	1.445	0.126	0.529	0.049
C2 + 1	1.945	0.130	1.058	0.083
C3 + 0.5	1.445	0.137	0.529	0.147
C3 + 1	1.945	0.153	1.058	0.279

C4 + 0.5	1.445	0.142	0.529	0.181
C4 + 1	1.945	0.162	1.058	0.353
C5 + 0.5	1.320	0.147	0.397	0.225
C5 + 1	1.790	0.181	0.894	0.514
		Amount	**7.640**	**2.060**

In comparison to the Weighted Product approach, the Simple Additive Weighting method has a total change of 7.64%, table 12 shows that the results of the sensitivity test from both, so that if further attention is paid to pay attention to the highest value in the SAW method it tends to be static / does not change when the weights of the first to fourth criteria are increased by adding a value of 0.5, namely the numbers 1.445 and 1.945 when added by 1. In contrast to the sensitivity test results of the WP method which are constantly changing. From this we can conclude why the SAW method is more suitable to be applied to a case study of scholarship recipient selection.

4. Conclusion

The outcomes of choosing scholarship recipients can be obtained using the Simple Additive Weighting approach, which starts with normalizing the matrix and calculates preference values to establish the ranking of the alternatives. Alternative 9 (MHS9) was selected as the recipient of the alternative scholarship based on the results of the SAW technique since it has the greatest preference value of 0.95. Given that it has the highest preference value of 0.12, option nine (MHS9) of the weighted product method is also picked for scholarship recipients. Furthermore, the findings of the sensitivity test conducted on the Simple Additive Weighting and Weighted Product techniques reveal that the SAW method has a total change of 7.64% while the WP method has a change of 2.06%. Thus, it can be inferred that the Simple Additive Weighting method is thought to be useful for addressing issues related to choosing scholarship recipients. The results obtained in the case study that we took could have been different if there had been a change in the number of criteria or a change in the weighting value of each criterion. For the future works, we can implement other algorithms which can produce higher sensitivity which can lead to a better performance.

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