Decision Support System For Student Scholarship Recipients Using Simple Additive Weighting Method with Sensitivity Analysis

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***Abstract* — The scholarship recipients should ideally be given to the appropriate students. Many methods have been widely used to assist the school management in deciding the scholarship recipients. However, such methods do not give additional information and other methods of comparison. The purpose of this research is to provide a systematic and objective scholarship selection recommendation system and using sensitivity analysis to compare the two decision support methods used, i.e. the Simple Additive Weighting and the Weighted Product methods. The Simple Additive Weighting method provides the highest assessment results, namely alternatives with a preference value of 13.27. The Weighted Product method provides the highest assessment results, namely alternatives with a preference value of 0.046. The results of the sensitivity analysis show that the total change value of the Simple Additive Weighting method was 6%, while in the Weighted Product method the total change value was 0.2%. Therefore, the sensitivity analysis showed that the Simple Additive Weighting method better than Weighted Product in determining the scholarship recipient recommendation because it has a greater total change value.**

Keywords—scholarship recommendation system, simple additive weighting, sensitivity analysis, weighted product

I. Introduction

Scholarships are a form of a grant in the form of money given to students to be used for tuition fees and other costs [1]. Some countries provide scholarships, for example in Indonesia, every citizen has the right to receive instruction, which is stipulated in the 1945 Constitution Article 31 (1). The scholarship program has been carried out by every educational institution in Indonesia, from elementary school to middle and higher school level. For higher-level education, there are several types of scholarships offered, namely: (1) scholarships given to students who have increased learning achievement, and (2) scholarships given to underprivileged students.

The scholarship award should be given to the right person. However, in its implementation, scholarships are sometimes given to inappropriate ones, this is due to the large number of assessment criteria that need to be considered in the selection process and the number of assessment alternatives that need to be selected objectively by considering the predetermined assessment criteria [2]. Such a selection process faces another problem i.e. there is no systematic and objective method. The selection process which is only carried out by comparing applicants' files with each other against the assessment criteria without any method allows for subjective assessments, errors in ordering or ranking, and the length of time required for the selection process. Therefore, a proper decision support system can be implemented for selection purposes.

A decision support method was proposed in providing the scholarship selection decision system is the Simple Additive Weighting (SAW) method and the Weighted Product (WP) method. The Simple Additive Weighting (SAW) method can select the best alternative from some candidates [2], [3]. The basic concept of this method is searching the weighted sum of the performance ratings in each alternative.

The efforts have been made to assist school for scholarship recipient recommendation using Simple Additive Weighting (SAW) [2], [4], [5]. Another method used a fuzzy-based system that showed rules or logic behind the system [6].

Some studies have compared the methods for scholarship recommendation system [3], [7], [8]. Other methods outperformed SAW, e.g. MCDM, TOPSIS, SMART, and other hybrids, only not more than 0.5% but the SAW method has a simple and fast characteristic [8], [9]. In the calculation process, the SAW method has a decision matrix normalization process (X) to a scale that can be compared with all available alternative values [10]. The Weighted Product method was also chosen as the selection method because it can determine the weight value of each attribute and with a ranking process, it will determine the student achievement according to the criteria. The weighted Product method is also considered more efficient because of the shorter time required for calculation [11].

In this study, the Simple Additive Weighting method and the Weighted Product method was used with an additional sensitivity analysis method. Sensitivity analysis is a process to determine the results of the comparison of decision support methods in problem-solving. This method will be used to find out how sensitive a method is if it is applied to solve a particular case. If a method has a high sensitivity value, it should be appropriate to be chosen to solve the problem [12], [13].

The paper contributes to DSS for scholarship recommendations with the sensitivity analysis as consideration for a user to decide the scholarship recipients. Therefore, the user has good assurance for his/her decision.

The paper is organized as follows. The method section discusses SAW, weighted product methods, and sensitivity analysis. The result and discussion show the SAW and weighted product performance based on sensitivity analysis before the conclusion.

II. Data and Method

A. Data

Data was collected with five criteria. The candidates for scholarship recipients were represented as the alternatives. SAW and WP methods were used to rank the alternatives as well as their sensitivity value.

The data consist of five criteria, i.e. grade point academic (GPA), semester, dependent, organization, and award. Alternatives are a candidate for scholarship recipients to be calculated by the proposed system.

B. Simple Additive Weighting (SAW)

The basic concept of SAW is finding the weighted sum of the performance ratings in each alternative. Therefore, the SAW method is also called the weighted addition method. It uses a decision matrix-normalization process (X) to be a scale and compared with all available alternative values [10].

Simple Additive Weighting method has typical steps as follows: 1) determining alternatives, 2) determining the assessment criteria, 3) determining the weight of each criterion, 4) normalizing the matrix, 5) making a normalized matrix, 6) determining the ranking of each alternative until finally a decision is obtained [10].

In determining the normalization matrix, the assessment criteria used should be determined first as the profit or the cost criteria. If the assessment criteria used are benefits, then determining normalization uses the equation (1):

$$r_{ij} = \frac{x_{ij}}{\text{Max } x_{ij}} \quad (1)$$

Where X is the matrix-normalization. Meanwhile, if the assessment criteria are the cost, the normalization matrix is calculated following the equation (2).

$$r_{ij} = \frac{\text{Min } x_{ij}}{x_{ij}} \quad (2)$$

Variable r_{ij} represents the normalized performance rating of the alternative Ai in the Cj attribute with variable i = 1,2,3, .., m and j = 1,2,3,… ..n. Variable Max x_{ij} represents the highest or maximum value of each row and column, Min xij is the lowest or minimum value of each row and column, and x_{ij} represents the row and column of the matrix. After determining the normalization of the matrix, a normalized matrix is generated.

The final step is to determine the preference value determined according to the equation (3):

$$Vi = \sum_{j=1}^{n} w_j \, r_{ij} \quad (3)$$

Variable Vi, w_{ij}, and r_{ij} represent the final value of the alternative, the weight of the predetermined criteria, and the value of the normalized matrix, respectively. The final result is calculated from the ranking process, i.e. by adding up the multiplication results between the normalized matrix and the weight vector. The best alternative is obtained based on the final preference score which has the highest value

C. Weighted Product (WP)

The study also used another method, The Weighted Product, which is a finite set of decision alternatives that are described in terms of several decision criteria. The basic concept of the Weighted Product method is to find the weighted multiplication of the performance rating for each alternative on all attributes that is also known as the weighted multiplication method [14].

The WP method has many stages, including 1) determining the alternative, 2) determining the assessment criteria, 3) determining the weight of each criterion, 4) normalizing the weight, 5) normalizing the matrix or determining the vector value S, 5) determining the vector V, 6) obtaining the decision result with the highest alternative value.

Weight normalization can be done by dividing the weight value by the total number of weights. The weight normalization calculation can be done using equation (4).

$$w_j = \frac{w_j}{\sum w_j} \quad (4)$$

Where w_j represents the weight of j criteria. Furthermore, to determine the vector S for objective criteria we rank the value of each criterion to the positive rank of each normalized weight result. Meanwhile, for the cost criteria, the vector S is determined by ranking the value of each criterion to the negative power of each normalized weight result. The calculation of the vector S can be done as in equation (5).

$$S_i = \prod_{j=1}^{n} {x_{ij}}^{w_j} \quad (5)$$

The final stage in determining the preference value is determined by dividing the result of the vector S for each alternative with the total number of vectors S. Vector V can be calculated using equation (6).

$$Vjn = \frac{Si}{\sum Si} \quad (6)$$

The chosen alternative is based on the highest value from the calculation of the weighted product method.

D. Sensitivity Analysis

Sensitivity analysis was used in this study to determine how sensitive is a method if it is applied to solve a particular case. If the sensitivity value is high, it shows a good result and the recommendation is appropriate. A high sensitivity value shows the more sensitive for each change in ranking,

[12], [13]. The degree of sensitivity (Sj) can be determined through several steps, namely: 1) determining all attribute weights wj = 1 (initial weight), 2) changing the weight of one criterion by increasing the weight value by 0.5 to 1, while the weights for other criteria remain, 3) calculate the percentage change in a ranking by looking at the change in the highest value resulting from each calculation compared to the conditions in the initial weight.

III. Result And Discussion

In determining the results of the scholarship recommendation decision, there are alternatives and assessment criteria used. The alternative used is students who register to take part in the scholarship selection process. The assessment criteria used are the cumulative grade point index (C1), semester (C2), number of dependents (C3), number of activities as a member of an organization (C4), and the number of certificates or certificates (C5). The assessment criteria used are profit criteria. Table I shows the data used in the process of determining the scholarship selection recommendation.

TABLE I. Alternative and Criteria Assessment

Alter-native	C1	C2	C3	C4	C5
A-1	4	2	3	1	1
A-2	2	2	2	3	1
A-3	4	2	1	3	1
A-4	4	2	2	3	1
A-5	5	2	2	2	1
A-6	5	3	3	2	2
A-7	4	3	2	1	2
A-8	4	2	2	2	1
A-9	3	2	2	2	1
A-10	3	2	3	2	1
A-11	4	2	5	2	1
A-12	3	2	4	2	1
A-13	2	2	2	1	2
A-14	3	2	5	2	1
A-15	4	3	4	2	1
A-16	4	3	2	3	1
A-17	4	3	3	2	1
A-18	5	3	2	2	1
A-19	5	3	3	2	1
A-20	4	3	2	2	1
A-21	5	3	2	2	1
A-22	5	2	2	2	1
A-23	5	2	2	2	1
A-24	5	2	2	2	1
A-25	5	3	2	2	1
A-26	4	3	3	1	2
A-27	5	3	2	2	1

After determining the alternatives and assessment criteria, we determined each criterion's weight. The criteria weights of C1, C2, C3, C4, and C5 are 5, 3, 1, 4, and 2, respectively.

A. *Simple Additive Weighting Result*

The initial stages of the Simple Additive Weighting method are determining alternatives, criteria, and weight of criteria.

TABLE II. Alternative and Criteria Assessment

Alternative	C1	C2	C3	C4	C5
A-1	3.47	2	3	0	0
A-2	3	2	2	2	0
A-3	3.35	2	1	2	0
…..	…..	…..	…..	…..	…..
A-27	3.73	4	2	1	0

The next step is to generate matrix normalization. Before normalizing the matrix, it is necessary to convert the assessment from the alternative data and existing assessments as shown in Table II. Table III shows the conversion results of the alternatives and the assessment criteria.

TABLE III. Matrix Normalization

Alternative	C1	C2	C3	C4	C5
A-1	4	2	3	1	1
A-2	2	2	2	3	1
A-3	4	2	1	3	1
…..	…..	…..	…..	…..	…..
A-27	5	3	2	2	1

The assessment criteria used are profit criteria. Therefore, in determining the normalization of the matrix, the equation formula (1) is used, i.e. by dividing the value of each attribute with the highest value of all alternatives in each criterion. The following is an example of calculation in determining the normalization of the matrix for the GPA criteria for the first and second alternatives as follows:

$$r_{11} = \frac{4}{5} = 0{,}8 \qquad r_{21} = \frac{2}{5} = 0{,}5$$

The calculations in determining the normalized matrix for the semester criteria for the first and second alternatives are as follows:

$$r_{12} = \frac{2}{3} = 0{,}67 \qquad r_{22} = \frac{2}{3} = 0{,}67$$

The calculations in determining the matrix normalization for the criteria for the number of dependents in the first and second alternatives are as follows:

$$r_{13} = \frac{3}{5} = 0{,}6 \qquad r_{23} = \frac{2}{5} = 0{,}4$$

The calculations in determining the matrix normalized for organizational-activity criteria in the first and second alternatives are as follows:

$$r_{14} = \frac{1}{3} = 0{,}33 \qquad r_{24} = \frac{3}{3} = 1$$

The calculations in determining matrix normalization of the reward/certificate criteria for the first and second alternatives are as follows:

$$r_{15} = \frac{1}{2} = 0{,}5 \qquad r_{25} = \frac{1}{2} = 0{,}5$$

After determining the normalization of the matrix, the final step is to determine the preference value for each alternative using equation (3). The preference value was obtained from the calculation results by adding the multiplication results between the normalized matrix and the weight vector. The best alternative was found based on the final preference score having the highest value. The following is an example of calculation in determining the preference value of the first alternative:

$$V_1 = (0{,}8*5)+(0{,}67*3)+(0{,}6*1)+(0{,}33*4)+(0{,}5*2)$$

$$V_1 = 8{,}93$$

Table IV shows the results of the scholarship selection recommendations using the Simple Additive Weighting method.

TABLE IV. SIMPLE ADDITIVE WEIGHTING RESULT

Alternative	Result
A-1	8,93
A-2	9,40
A-3	11,20
…..	…..
A-27	12,07

SAW results show that the highest preference value is the sixth alternative (A-6) with a preference value of 13.27. Fig 1 shows the calculation results of the SAW method for each alternative in determining the scholarship selection.

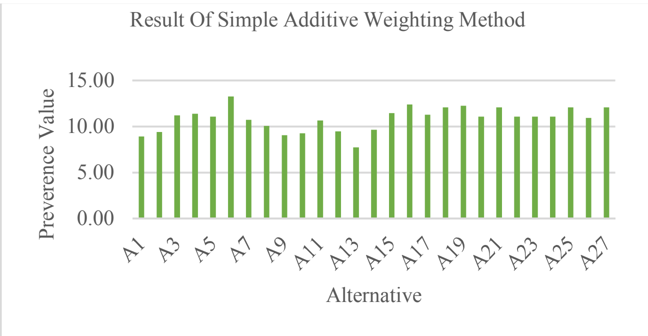

Fig. 1. Result of Simple Additive Weighting Method

B. *Weighted Product Result*

The initial stage of the Weighted Product method is determining alternatives, determining criteria, determining the weight of the criteria. The next step is weight normalization by dividing the weight of the criterion assessment with the total weight of the criteria rating using equation (4).

Following is the calculation result of the weighted normalization for each weighting criterion:

$$w_1 = \frac{5}{5+3+1+4+2} = \frac{5}{15} = 0{,}333$$

$$w_2 = \frac{3}{5+3+1+4+2} = \frac{3}{15} = 0{,}2$$

$$w_3 = \frac{1}{5+3+1+4+2} = \frac{1}{15} = 0{,}067$$

$$w_4 = \frac{4}{5+3+1+4+2} = \frac{4}{15} = 0{,}267$$

$$w_5 = \frac{2}{5+3+1+4+2} = \frac{2}{15} = 0{,}133$$

The next step was determining the S vector using equation (5). The assessment criterion used is the profit criterion, hence, the S vector is determined by ranking the value of each criterion to the positive rank of each normalized weight result.

The following is an example of calculating the value of the vector S in the first and second alternatives

$$S_1 = 4^{(0{,}333)} \times 2^{(0{,}2)} \times 3^{(0{,}067)} \times 1^{(0{,}267)} \times 1^{(0{,}133)}$$

$$S_1 = 1{,}962$$

$$S_2 = 2^{(0{,}333)} \times 2^{(0{,}2)} \times 2^{(0{,}067)} \times 3^{(0{,}267)} \times 1^{(0{,}133)}$$

$$S_2 = 2{,}032$$

The final step in the Weighted Product method is to determine the preference value determined by dividing the result of the vector S for each alternative by the total number of vectors S according to equation (6).

Following is the calculation result in determining the V vector or the result preference value of ranking each alternative using the Weighted Product method for the first and second alternatives.

$$V_1 = \frac{1{,}962}{65{,}694} = 0{,}030$$

$$V_2 = \frac{2{,}032}{65{,}694} = 0{,}031$$

Table V shows the results of vector S and vector V for each alternative.

TABLE IV. WEIGHTED PRODUCT RESULT

Alternative	Vector S	Vector V
A-1	1,962	0,030
A-2	2,032	0,031
A-3	2,444	0,037
…..	…..	…..
A-27	2,684	0,041
Total	65,494	1,000

Based on the Weighted Product results, it shows that the alternative having the highest preference value is the sixth alternative (A-6) with a preference value of 0.046. Fig 2 shows the graph of the calculation results of the Weighted Product method for each alternative in the process of determining the scholarship selection.

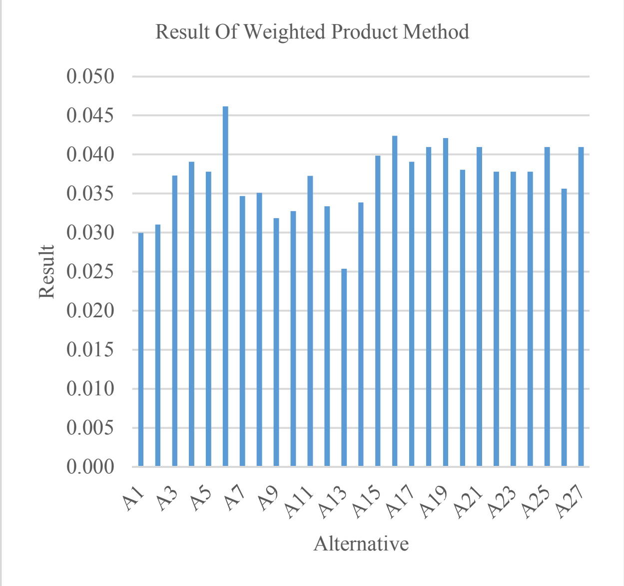

Fig. 2. Result of Weighted Product Method

C. *Sensitivity Analysis*

Based on the Simple Weighting Product decision method and the Weighted Product method, the next process is to perform a comparative analysis using the sensitivity analysis technique. Sensitivity analysis is conducted to find out how sensitive a method is when it is applied to solve a particular case. If a method has a high sensitivity value or having more sensitive from each change in ranking, the method is significant.

Initial calculation results from both methods were obtained using initial weights (5; 3; 1; 4; 2). Table V shows the results of the initial calculation of the Simple Additive Weighting method and the Weighted Product method.

The weight of one criterion only change while the weights for the other criteria are fixed, then an analysis of the change in the maximum value is done that occurs from the initial conditions with the changing conditions. Table VI shows the comparison between SAW and WP results.

TABLE VI. SAW AND WP RESULT

Alternative	SAW Method	WP Method
A-1	0,0893	0,030
A-2	0,0940	0,031
A-3	0,1120	0,037
…	…..	…..
A-27	0,1207	0,041
Max	0,1327	0,046

The next step in conducting a sensitivity analysis is to change the weight of one criterion by increasing the weight value by 0.5 to 1, while the weights for the other criteria are fixed. Then after all the weights of each assessment criterion have been changed, we calculate the percentage change in a ranking by looking at the change in the highest value resulting from each calculation compared to the conditions in the initial weight. Table VII shows the results of a thorough sensitivity analysis.

TABLE VI. SENSITIVITY ANALYSIS RESULT

Criteria	Max SAW	Max WP	Sensitivity Analysis	
			SAW	*WP*
Initial	0,1327	0,046		
W1 +0,5	0,1377	0,046	0,5%	0%
W1 +1	0,1427	0,046	1%	0%
W2 +0,5	0,1377	0,046	0,5%	0%
W2 +1	0,1427	0,046	1%	0%
W3 +0,5	0,1357	0,046	0,3%	0%
W3 +1	0,1387	0,046	0,6%	0%
W4 +0,5	0,1360	0,046	0,33%	0%
W4 +1	0,1393	0,046	0,66%	0%
W5 +0,5	0,1377	0,047	0,5%	0,1%
W5 1	0,1427	0,047	1%	0,1%
Total			6%	0,2%

The Simple Additive Weighting method provides the highest assessment results, namely alternatives with a preference value of 13.27. The Weighted Product method provides the highest assessment results, namely alternatives with a preference value of 0.046. The results of the sensitivity analysis show that the total change value of the Simple Additive Weighting method is 6%, while in the Weighted Product method the total change value is 0.2%.

Fig 3 shows the user interface of the scholarship recommendation system. The candidate scores can be seen in csv format. The user can also see the performance of both methods from the sensitivity analysis result in the proposed system.

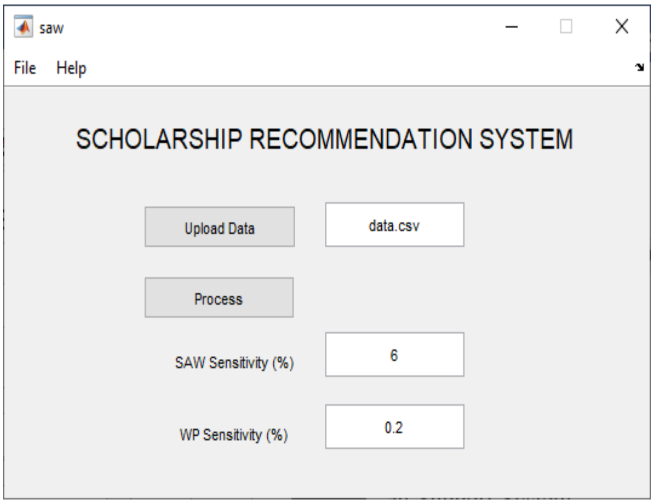

Fig. 3. DSS User Interface

IV. CONCLUSION

The Simple Additive Weighting method and the Weighted Product method was implemented as a solution to supporting the scholarship recommendation system. In determining the results of the scholarship selection recommendations, five assessment criteria are considered, namely cumulative grade point index, semester, number of dependents, number of participation in organizations, and number of certificates or certificates. The result showed that the Simple Additive Weighting method is considered more suitable for determining the scholarship selection recommendation because it has a greater total change value. Sensitivity analysis can be integrated into the decision support system as additional consideration for the user about the recommendation results. Other methods, such as fuzzy MADM, TOPSIS, etc. can also be included in DSS for the next research.

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