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Academic Majors Recommendation Using Analytical Hierarchy Process and Multi-Objective Optimization on the Basis of Ratio Analysis

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ABSTRACT

In determining an academic majors, the mere information about the departments is not sufficient as the base of taking the decision as one would only know popular majors without being aware of his/her potential. There are also limited recommendations obtained through counseling guidance. By using the Analytical Hierarchy Process (AHP) and Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) methods, prospective students get the recommendations of academic majors by putting their preference criteria for the majors. The criteria used are affordable study costs, accreditation of majors, department facilities, student potential to the majors, student interest in majors, future goals, parental advice, self-desire, peer influence, report card scores, previous achievements, passing grade majors and length of study. The Spearman's Rank Correlation method was used to determine the results of the correlation ranking recommendations from the teacher (guidance and counseling teacher) and the system where the weights obtained from the teacher (guidance and counseling teacher) and from the students who filled it through the system. Based on the correlation of the system ranking with the guidance and counseling teacher ranking to 25 students majoring in Natural sciences class XII, the average value of accuracy was 88% with a standard deviation of 0.13. As for the students majoring in social sciences, the average value of accuracy was 97% with a standard deviation of 0.03. From this research, it can be concluded that the Analytical Hierarchy Process (AHP) and Multi Objective Optimization on the basis of Ratio Analysis (MOORA) methods can be used in helping to solve decision-making problems in the recommendation system of academic majors.

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1. INTRODUCTION

Determining the appropriate majors in higher education is a problem that is always experienced by students of class XII, they always get indecisive about choosing between the many majors (Diponegoro, 2009). Not having information related to academic majors is also a problem and the students only tend to look for popular majors without knowing their own potentials. This is an internal factor that becomes an obstacle in determining academic majors. Advice from parents is also an external factor in determining academic majors (Vinsensia & Utami, 2018). To solve this problem, students usually will consult directly with the guidance and counseling teacher, but in recommending the majors, the guidance and counseling

teacher still manually assesses the students from the results of report cards and personal views without considering other supporting criteria, so it takes a long and repetitive process for both the teacher and student.

The wrong decision in the majors can lead to problems in the future, for example, the reluctance in the study which results in decreased academic quality due to the wrong choice of majors. To support suitable choice, students must consider several supporting criteria in addition to the subject grade criteria, and the guidance and counseling teacher in the process of recommending a majors must consider the criteria that fit the student.

Based on previous research, Anggraeni et al. (2017) and Aminudin et al. (2018), used the SAW to determine the best campus in Pringsewu. Anggraeni et al. (2017) used the criteria were obtained through the results of the questionnaire, namely buildings, fees, entry tuition fee, tuition fees per semester, library, laboratory facilities, campus accreditation, educational scholarships, percentage of alumni. Based on the answers to the questionnaire, the study obtained 6 priority criteria. By using 3 alternatives and benchmarks such as very low, low, medium, high, very high. From the 3 alternatives, the A1 alternative is the best campus with the result of v1 = 0.924, v2 = 0.857, dan v3 = 0.8495. Aminudin et al. (2018) used academic achievements, graduate lecturers, extracurricular activities, accreditation, facilities, and scholarships as criteria.

Other research related to selection of academic majors at Universitas Dian Nuswantoro (Kusumaningrum et al., 2017). By using the Association Rule technique, prospective students can determine the desired academic majors under the profile of their parents' salary and their wishes. Forward Chaining also used as the method based on student interests and talents (Mulyani et al., 2018). This study started by listing 9 types of intelligence, then the students answered the questions about the characteristics of intelligence. The results of these answers became a reference in making a decision tree according to the student in the form of the majors that matches the score obtained. Then the study conducted in recommending campuses for applicants where the system used 3 channels: admin, alumni, prospective students (Monali et al., 2018). The recommendation system worked with a review and rating by alumni, but the alumni's opinion must have been validated by the admin. The prospective students could find out which campus was suitable for them according to the alumni review or they could find out the campuses that were in accordance with prospective student priorities such as campus location, costs, and others.

Another research related to the selection of academic majors used the User Preference and Analytical Hierarchy Process (AHP) approach, where the alternatives used were the majors at Gadjah Mada University (Khuntary & Ferdiana, 2015). Based on the trials conducted on two students, it was found that student 1 was more concerned with the criteria of Holland's interest with a priority weight of 0.633 with the appropriate majors in Nursing and midwifery. There is also a research related to the decision support system used to select academic majors using SAW and AHP (Marbun & Hansun, 2019). The level of satisfaction related to this decision support system was 77.22%.

AHP is one of the Multi Criteria Decision Making (MCDM) methods that is consistent in decision making (Andika & Hasugian, 2020). This method can provide the best order that produces the criteria and alternatives with the highest score (Danang et al., 2020). However, for a large number of criteria and alternatives, the AHP method is less effective. To cover the weakness in AHP, a different decision-making method is needed, which is the Multi-Objective Optimization method on the basis of Ratio Analysis (MOORA). MOORA can be used for optimizing different attributes appropriately, and also in the subjective assessment process separated.

2. RESEARCH METHODE

The general architecture in this study can be seen in Fig. 1. The stages of the process are as follows:

Student Data Input

Students input their data such as student name, sex, report card scores, past achievements, and student ratings of criteria for alternative academic majors. Student data were used to determine the recommendation process which was done manually by the guidance and counseling teacher (as an expert) and the results of the recommendations by the system. This study used 25 students from the Natural Sciences majors and 21 students from the Social Sciences majors class XII.

Criteria Data Input

There were 13 criteria data used in determining academic majors using the AHP and MOORA methods, some of those criteria were filled by the students, they were student potential to the majors, student interest in majors, future goals, parental advice, self-desire, peer influence, report card scores, and previous

achievements. The following Fig. 2 is an example of the input results from students majoring in Natural Science for the student data section and the intensity data criteriaescriptive Analysis.

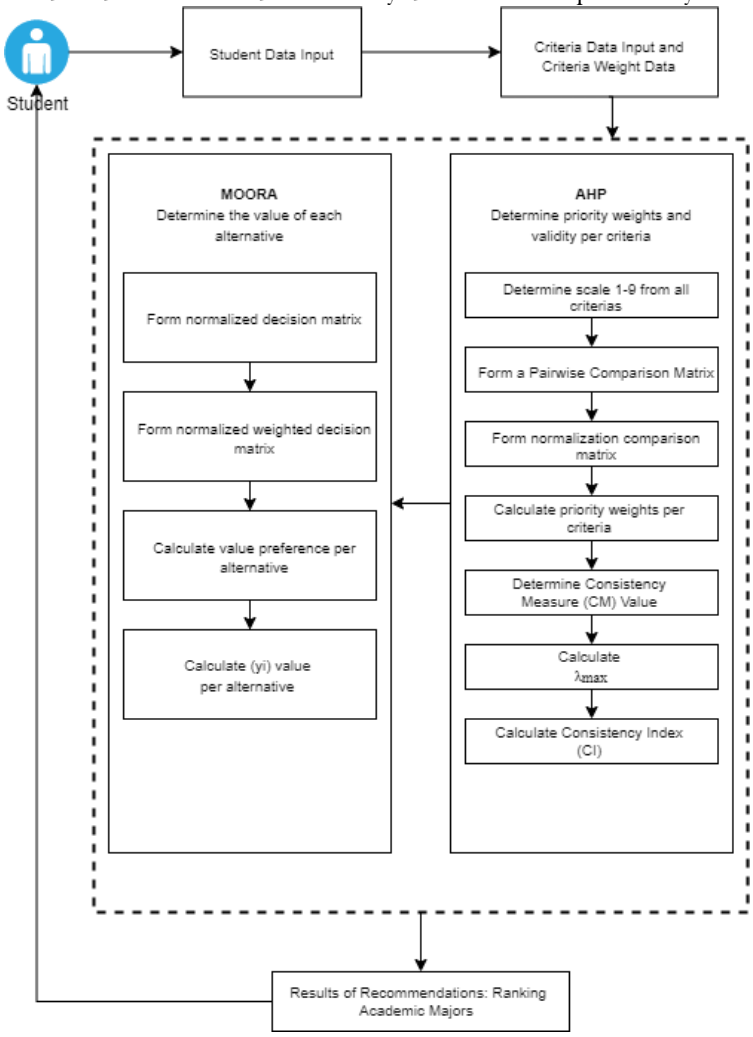

Fig. 1 General Architecture

Criteria Weight Data

The importance level of each criterion depends on the weight obtained, where the weight of the criteria comes from the AHP questionnaire which was answered by 25 students of class XII majoring in Natural Sciences and 21 students majoring in Social Sciences because each student has their own criteria weight in determining academic majors. The weight according to the teacher (guidance and counseling teacher) and some students can be seen in Table 1.

Table 1. Weight Criteria from the Teacher and Natural Sciences Majors Student

No	Criteria	From the Teacher	From the Student
1.	Affordable study costs	0.141	0.078
2.	Accreditation of majors	0.085	0.039
3.	Department facilities	0.074	0.058
4.	Student potential to the majors	0.069	0.057
5.	Student interest in the majors	0.082	0.116
6.	Future goals	0.113	0.196
7.	Parental advice	0.057	0.063
8.	Self-desire	0.079	0.087
9.	Peer influence	0.055	0.014
10.	Report card scores	0.062	0.078
11.	Previous achievements	0.06	0.058

12.	Passing grade of the majors	0.069	0.108
13.	Length of study	0.055	0.047

Name	M.Rizwan Sitorus					
Majors	Natural Science					
Sex	Male					
Criteria	Potential to the majors					
	No potential					
Criteria	**Interest in majors**					
	Very interested	1. Mechanical Engineering 2. Electrical Engineering				
Criteria	**Future goals**					
	Quite Suitable	1. Mechanical Engineering 2. Electrical Engineering				
Criteria	**Parental advice**					
	Strongly Not Recommend					
Criteria	**Self-desire**					
	Sangat Menginginkan	1. Mechanical Engineering 2. Electrical Engineering				
Criteria	**Peer influence**					
	Quite Influential	1. Architecture				
Criteria	**Report card scores**					
	Subject	I	II	III	IV	V
	Bahasa Indonesia	85	77	77	80	85
	English	76	76	75	75	83
	Mathematics	70	77	70	70	85
	Physics	75	75	75	75	83
	Chemistry	77	77	75	80	85
	Biology	80	75	75	75	83
	Average					
Criteria	Previous achievements					
	None					

Fig. 2 Student Data and Criteria Input

AHP Process Flow

Forming a Pairwise Comparison Matrix

Forming a matrix of pairs on the kinds of criteria for academic majors by giving a scale of 1-9 by students. Pairwise comparisons between students were different. The example is shown in Table 2.

Calculating the Normalized Matrix

After determining the paired matrix, it proceeded to calculate the column value divided by the total results per column in order to obtain a pairwise comparison normalization matrix. The example of calculating the normalization matrix for the data of a Natural Sciences Majors student is shown below.

Normalization matrix (first row)

= (1/31.769 + 1/38.200 + 1/31.400 + 0.333/34.066 + 0.333/ 22.987 + 0.142/5.336 + 1/15.533 + 0.142/17.685+ 1/58.333+ 0.2 / 10.600 + 1/21.533 + 0.142 / 26.104 + 5 / 23.666)

= 0.512

The calculation was done until the thirteenth row then summed up.

Table 2. Matrix of Comparison of Social Sciences Majors Student Criteria

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13
K1	1	1	1	1/5	1/5	1/9	1/3	1/9	5	1	1	1	5
K2	1	1	3	1/5	1/5	5	1	1	3	1	5	3	1/5
K3	1	1/3	1	1	1/5	1/5	1	1	5	1/9	7	1/9	1/5
K4	5	5	1	1	1/5	5	1	1/5	5	1/7	5	1	1/7
K5	5	5	5	5	1	5	1/7	1/7	1/5	5	9	1	1/9
K6	9	1/5	5	1/5	1/5	1	7	3	1/5	1/9	1/7	7	5
K7	3	1	1	1	7	1/7	1	7	1/9	5	1	1/5	5
K8	9	1	1	5	7	1/3	1/7	1	1/5	5	1/7	1	5
K9	1/5	1/3	1/5	1/5	5	5	9	5	1	1/9	9	1	1/3
K10	1	1	9	7	1/5	9	1/5	1/5	9	1	7	1/9	1/3
K11	1	1/5	1/7	1/5	1/9	7	1	7	1/9	1/7	1	1	1/3
K12	1	1/3	9	1	1	1/7	5	1	1	9	1	1	1/5
K13	1/5	5	5	7	9	1/5	1/5	1/5	3	3	3	5	1
Total	37.400	21.400	41.342	29.000	31.311	38.130	27.019	26.854	32.822	30.619	49.285	22.422	22.854

Determining the Priority Weight

The priority weight was obtained from the sum of normalization divided by the number of elements/criteria (n = 13) for each criterion. The example of the priority weights obtained for one of the students is as follows;

Affordable study costs (K1) : 1.011 / 13 = 0.078
Accreditation of majors (K2) : 0.512 / 13 = 0.039
Department facilities (K3) : 0.758 / 13 = 0.058
Student potential to the majors (K4) : 0.747 / 13 = 0.057
Student interest in the majors (K5) : 1.506 / 13 = 0.116
Future goals (K6) : 2.548 / 13 = 0.196
Parental advice (K7) : 0.819 / 13 = 0.064
Self-desire (K8) : 1.127 / 13 = 0.087
Peer influence (K9) : 0.187 / 13 = 0.014
Report card scores (K10) : 1.008 / 13 = 0.078
Previous achievements (K11) : 0.751 / 13 = 0.058
Passing grade of the majors (K12) : 1.409 / 13 = 0.108
Length of study (K13) : 0.617 / 13 = 0.047

Measuring Consistency

When measuring consistency, the consistency measure (cm) was obtained from multiplying the value in the paired matrix as in Table 2 with the weight priority results in each row, as for the example:
Consistency Measure (first row)

= [(1×0.078) + (1×0.039) + (0.2×0.058) + (7×0.057) + (0.111×0.116) + (1×0.196) + (1×0.064) + (1×0.087) + (7×0.014) + (0.2×0.078) + (3×0.058) + (7×0.108) + (1×0.047)]

= 1.817 up to the thirteenth row

Calculating Consistency Ratio

The next stage was finding the Consistency Index (CI) value with the formula of:

$$CI = \lambda_{max} - n / n - 1 \quad (2.1)$$

The calculation example is as follows:

λ_{max} = (1.817 + 0.677 + 1.133 + 0.99 + 2.274 + 4.553 + 1.181 + 1.979 + 0.267 + 1.526 + 1.067 + 2.536 + 0.84) / 13

= 1.603

n was the number of criteria, which was 13. so that the CI value = (1.603 - 13) / (13-1) = -0.949. After that the Consistency Ratio (CR) was obtained with CI divided by IR. Previously, the index ratio (IR) value was determined based on Saaty's theory (Saaty, 2000) according to the number of criteria, IR = 1.56 so CR = -0.949 / 1.56 = - 0.609. When the CR 0-0.1, it was considered consistent. more than that it was inconsistent.

MOORA

MOORA is a method introduced by Brauers and Zavadkas and first used in multi-criteria decision-making by Brauers (Hanifatulqolbi et al., 2018). This method has a good level of selectivity in determining an alternative where the criterion value has a value that is liked or not (Sa'adati & Fadli, 2018). The alternative majors used in this study are the undergraduate majors at the Universitas Sumatera Utara with a total of 47 majors. The majors data were divided into 2 groups, 25 of Natural Sciences majors and 22 of Social Sciences majors. The process steps for the MOORA method are as follows:

Making a Moora decision matrix with the following equation:

$$\mathbf{X}=\begin{bmatrix} x_{11} & \cdots & x_{1i} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{j1} & \cdots & x_{ij} & \cdots & x_{jn} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mi} & \cdots & x_{mn} \end{bmatrix}.$$

Note :

x_{ij} = alternative response j to criterion i

i = 1, 2, 3, 4,..., n is the sequence number of the attribute or criterion

j = 1, 2, 3, 4,..., m is the alternate sequence number

X = Decision Matrix

The decision matrix in this study was as follows:

$$\mathbf{X}=\begin{bmatrix}
5&5&5&1&1&1&1&1&1&3&1&1&3\\
5&5&5&1&1&1&1&3&1&3&1&1&3\\
5&5&3&1&1&1&1&1&1&3&1&1&3\\
5&5&5&1&1&1&1&1&1&3&1&1&1\\
5&5&5&1&1&1&1&1&1&3&1&1&1\\
5&4&3&1&1&1&1&1&1&3&1&5&1\\
5&5&3&1&1&1&1&1&1&3&1&5&1\\
5&5&3&1&1&1&1&1&1&3&1&5&1\\
5&5&3&1&1&1&1&1&1&3&1&3&1\\
5&4&3&1&1&1&1&1&1&3&1&5&1\\
5&4&3&1&1&1&1&1&1&3&1&3&1\\
5&5&3&1&3&3&1&3&3&3&1&1&1\\
5&5&3&1&3&3&1&3&3&3&1&1&1\\
5&5&3&1&3&3&1&3&3&3&1&1&1\\
5&4&3&1&3&3&1&3&3&3&1&1&1\\
5&5&3&1&3&3&1&3&3&3&1&1&1\\
5&5&3&1&3&3&1&3&3&3&1&1&1\\
5&4&3&1&3&3&1&3&3&3&1&1&1\\
5&4&3&1&1&1&1&1&1&3&1&3&1\\
5&5&3&1&1&1&1&1&1&3&1&3&1\\
5&4&3&1&1&1&1&1&1&3&1&3&1\\
5&5&3&1&1&1&1&1&1&3&1&3&1\\
5&5&5&1&1&1&1&1&1&3&1&1&3\\
5&5&5&1&1&1&1&1&1&3&1&1&1\\
5&4&3&1&1&1&1&1&1&3&1&5&3
\end{bmatrix}$$

The second step was to create a normalized decision matrix with the following formula:

$$X_{ij}^{*}=\frac{x_{ij}}{\sqrt{\left[\sum_{j=1}^{m} x_{ij}^{2}\right]}} \qquad (2.2)$$

Note :

X_{ij} = Alternative matrix j on criterion i

i = 1, 2, 3, 4,..., n is the sequence number of the attribute or criterion

j = 1, 2, 3, 4,..., m is the alternate sequence number

X_{ij}^* = Alternative j normalization matrix on the calculation criteria carried out up to the 13th criterion.

The third step was the process for a weighted normalized decision matrix derived from AHP priorities used to be constants, as in the following example:
$y_{1,1}$ (K1) = (0.078) (0.2) = 0.0156 the calculation was performed to all columns per criterion

The fourth step was to calculate the preference value by adding up the benefit and the cost attributes of each academic majors with the following formula:

$$y_j^* = \sum_{i=1}^{i=g} X_{ij}^* - \sum_{i=g+1}^{i=n} X_{ij}^* \quad (2.3)$$

Note:
i = 1,2,...,g- criteria/attribute with maximized status;
i = g + 1, g+2, ..., n – criteria/attribute with minimized status
y_j^* = Max-min Normalized Matrix

Benefit = K1+K2+K3+K4+K5+K6+K8+K10+K11
Cost = K7+K9+K12+K13

The fifth step was to calculate the value (yi) by subtracting the maximum value from the minimum value for each alternative majors. The formula used was

$$y_i = \sum_{j=1}^{g} w_j \, x_{ij}^* - \sum_{j=g+1}^{n} w_j \, x_{ij}^* \quad (2.4)$$

Note:

i = 1,2,...,g- criteria/attribute with maximized status;
i = g + 1, g+2, ..., n – – criteria/attribute with minimized status
W_j = Weight to j
y_i = The normalized assessment value from alternative 1 to all attributes.

Based on the formula, the yi value was:
Yi = yi_{max} – yi_{min}
= 0,141 – 0,041
= 0,1

Output

Based on the process steps using the AHP and MOORA methods, the biggest alternative was the best alternative for natural science students with 25 majors obtained with a score of 0.23 for Electrical Engineering majors and the smallest value of 0.061 for the forestry majors.

3. RESULT AND ANALYSIS

The testing of the data obtained and the capabilities of the system being built was carried out in this stage. The test matched the results of the system recommendations with the results of manual recommendations from the guidance and counseling teacher. The tests were conducted on 25 students majoring in natural sciences and 21 students majoring in social sciences. The Spearman's Rank Correlation is a method for performing nonparametric calculations used to determine the relationship between two data sets that contain a ranking list (Siregar et al., 2019). In this research, Spearman's Rank Correlation was used to determine the results of the correlation ranking recommendations from the teacher (guidance and counseling teacher) and the system where the weights obtained from the teacher (guidance and counseling teacher) and from the students who filled it through the system. It is as shown in Table 3.

Table 3. Results of System Testing for a Student (M. Rizwan Sitorus)

No	Academic Majors	Teacher Ranking	System Ranking	Correlation
1	Doctor Education	10	11	
2	Dentist Education	10	11	
3	Public Health Sciences	19	14	
4	Pharmacy	3	3	
5	Nursing Science	3	3	
6	Agribusiness	23	23	
7	Agroecotechnology	21	21	
8	Ranch	21	21	
9	Food Science and Technology	13	15	
10	Management of Aquatic Resources	23	23	
11	Agricultural Engineering	16	18	
12	Architecture	20	10	
13	Electrical Engineering	1	1	0,94
14	Industrial Engineering	6	6	
15	Civil Engineering	8	8	
16	Chemical Engineering	6	6	
17	Mechanical Engineering	1	1	
18	Environmental Engineering	8	8	
19	Mathematics	16	18	
20	Biology	13	15	
21	Physics	16	18	
22	Chemistry	13	15	
23	Computer science	10	11	
24	Information Technology	3	3	
25	Forestry	25	25	

In the test of one student with the name M. Rizwan Sitorus majoring in Natural Sciences, the correlation between the ranking of guidance and counseling teacher and the system was 0.94, where the highest priority was the future goals criteria with a value of 0.196 and the least priority came from the peer influence criteria with a value of 0.014. The top 5 results of academic majors from system recommendations were Electrical Engineering, Mechanical Engineering, Pharmacy, Nursing Science, and Information Technology.

Based on the correlation of the system ranking with the guidance and counseling teacher ranking to 25 students majoring in Natural sciences class XII, the average value of accuracy was 88% with a standard deviation of 0.13. As for the students majoring in social sciences, the average value of accuracy was 97% with a standard deviation of 0.03.

4. CONCLUSION

Based on the study obtained in recommending academic majors, it can be concluded that the AHP and MOORA methods can be used in helping to solve decision-making problems in the recommendation system of academic majors. The use of the AHP method obtained the priority over 13 criteria and tested the consistency of each criterion, the priority criteria was obtained based on the assessment conducted by the students. To obtain a level of research accuracy, the correlation between the system and the results of the manual assessment from the guidance and counseling teacher used the Spearman's Rank Correlation method that obtained the correlation of 88% for 25 students majoring in Natural Sciences class XII with a standard deviation of 0.13 and 97% for 21 students majoring in Social Sciences class XII with a standard deviation of 0.03. The difference in the ranking order of the system recommendations and guidance and counseling teacher recommendations was due to the weight. The weight prioritized by the teacher was different from the weight of the student. It was also affected by the guidance and counseling teacher's opinion regarding the lack of alternative college majors offered in this study. However, these results provide recommendations for over one academic major for prospective students compared to research conducted by Vincent & Utami (2018) which only has one academic major (Informatics Engineering) without the expert validation.

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