Mathematics Letters, 1(1): 79-91, 2022

APPLICATION OF ANALYTIC HIERARCHY PROCESS (AHP) AND SIMPLE ADDITIVE WEIGHTING (SAW) METHODS IN SELECTING THE BACHELOR'S DEGREE PROGRAM IN UiTM

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ABSTRACT

Nowadays, choosing a bachelor’s degree program is a hard decision to make due to many reasons such as the variety of choices of university, programs and the courses offered by the program and many more. Therefore, to overcome this confusion, there are some methods from Multiple Criteria Decision Making (MCDM) that are reliable and suitable methods to solve this problem. In the decision-making model, the hybrid of Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW) methods are the methods that will be implemented into this research. These methods provide a base for decision making processes where there are several alternatives with many criteria. In this project, some bachelor’s degree programs from Faculty of Computer and Mathematical Sciences (FSKM) Universiti Teknologi Mara (UiTM) are considered as the alternatives with multiple courses offered as the criteria, weighted and ranked using AHP-SAW methods. The template of these methods was created using Microsoft Excel software. One of the respondents’ data included in this paper to illustrate the application of this hybrid method. Based on the result, the top three of highest weight of criteria are Mathematics, Operation Research and Statistics. The first rank of alternative is Bachelor of Science (Hons.) Management Mathematics (CS248) and after the calculation for all respondents, the rate of accuracy of this method is 92.85%.

Keywords*: AHP-SAW, Alternative, Analytic Hierarchy Process (AHP), Bachelor’s Degree Program, Criteria, Simple Additive Weighting (SAW)*

Received for review: 10-04-2022; Accepted: 17-04-2022; Published: 30-04-2022

1. Introduction

Universiti Teknologi Mara (UiTM) is one of the local universities in Malaysia which consists of various faculties and courses. One of the faculties is Faculty of Computer and Mathematical Science (FSKM). This faculty was established in the year of 1966 as the School of Actuarial Science, Statistics, Mathematics, Econometrics and Cybernetics (ASMEC) and has been developed since then and renamed as FSKM since 2009 up till now (FSKM, 2020).

This research will be targeting a part of students from this faculty which is students who studied either in Bachelor of Computer Science (Hons.) (CS230), Bachelor of Science (Hons.) Computational Mathematics (CS247), Bachelor of Science (Hons.) Management Mathematics (CS248), Bachelor of Science (Hons.) Mathematics (CS249), Bachelor of Information System (Hons.) Business Computing (CS264), Bachelor of

Science (Hons.) Mathematical Modelling and Analytics (CS267) and Bachelor of Computer Science (Hons.) Mobile Computing (CS270).

Choosing the correct professional route is becoming increasingly vital for today's young graduates. When deciding on a profession and a degree course, students must consider a variety of factors (Rico-Briones and Bueno, 2019). There are various aspects that may influence students' decisions, and would be a useful source of information for private higher education institutions to provide excellent services that will meet their requirements, expectations, and desires (Vaz and Mansori, 2013).

This research aims to help in finding the best selection of bachelor's degree program using a mathematical approach. The selection will be involving several criterions that will help in the judgement which are finding the weightage of each criterion, then rank the alternatives based on the weight of criterions. In order to calculate the accuracy of this method, actual data is needed to be compared with the outcome from this approach.

2. Methodology and Implementation

In this section, implementation of the AHP-SAW method is shown by the whole process computation that starts with identifying the criteria until the end of the process to complete the process of ranking the alternatives and calculating the accuracy of these methods. The results of this research are determined by the weightage obtained by each bachelor's degree programs' courses. A survey was conducted by distributing questionnaires to target respondents using Microsoft Form and the list of alternatives which are the bachelor's degree programs as in Table 1.

Table 1. Number of Respondents of Each Bachelor's Degree Program (Alternative)

Bachelor's Degree Program (Alternatives)	**Code**	**Number of Respondent**
Bachelor of Computer Science (Hons.)	CS230	10
Bachelor of Science (Hons.) Computational Mathematics	CS247	10
Bachelor of Science (Hons.) Management Mathematics	CS248	10
Bachelor of Science (Hons.) Mathematics	CS249	10
Bachelor of Information System (Hons.) Business Computing	CS264	10
Bachelor of Science (Hons.) Mathematical Modelling and Analytics	CS267	10
Bachelor of Computer Science (Hons.) Mobile Computing	CS270	10

This research considers ten criteria that can influence the ranking of the alternatives. Each criterion represents the major courses offered at least by three of the bachelor's degree programs as shown in Table 2.

Table 2. List of Criteria

Criteria	**Code**
Mathematics	MAT
Computer Science	CSC
Information System	ISP
Statistics	STA
Operation Research	QMT
Information and Communication Technology	ICT
Accounting	ACC
Economics	ECO
Data Sciences	DSC
Networking	ITT

Table 3 shows the decision matrix which represents the number of subjects based on criterions for each alternative derived from each bachelor's degree programs' course outline.

Table 3. Decision Matrix

	Criterion									
Alternative	MAT	CSC	ISP	STA	QMT	ICT	ACC	ECO	DSC	ITT
CS230	2	21	0	1	0	3	0	0	0	1
CS247	16	5	0	1	1	0	0	0	0	0
CS248	13	1	1	2	3	0	1	1	1	0
CS249	16	1	1	2	1	0	2	1	1	0
CS264	2	5	14	1	0	2	1	0	0	1
CS267	14	3	3	2	1	1	0	1	2	0
CS270	2	15	5	1	0	1	0	0	0	2

Before calculation for AHP starts, the weightage preference needs to be determined. The criteria weight will be defined by comparing each criterion in pairs. The Priority of Criterions Scale (Taherdoost, 2017) will be used for the comparing process as in Table 4.

Table 4. Priority Criterion Scale

Scale	Description
1	Both criterions are equally a priority.
3	One criterion is a little more priority than another one.
5	One criterion is more priority than another one.
7	One criterion is obviously more priority than another one.
9	One of the most priority criteria.
2, 4, 6, 8	Values that are in between two consecutive priority values.
Inverse	If for criterion ‘i’ gets one value over criterion ‘j’, then ‘j’ has the opposite value than ‘i’.

One of the respondent’s data will be used to show the implementation of this study. The current course that has been taken by this specific respondent is CS248. The pairwise comparison matrix as in Table 5 below.

Table 5. Pairwise Comparison Matrix

	MAT	CSC	ISP	STA	QMT	ICT	ACC	ECO	DSC	ITT
MAT	1	5	5	5	5	5	5	5	5	5
CSC	1/5	1		1	1/6	1	1/5	1	1	1
ISP	1/5	1	1	1/6	1/6	1	1/5	1	1	1
STA	1/5	1	6	1	1/6	5	1/5	5	5	5
QMT	1/5	6	6	6	1	5	5	6	5	5
ICT	1/5	1	1	1/5	1/5	1	1	1	1	1
ACC	1/5	5	5	5	1/5	1	1	1	1	1
ECO	1/5	1	1	1/5	1/6	1	1	1	1	1
DSC	1/5	1	1	1/5	1/5	1	1	1	1	1
ITT	1/5	1	1	1/5	1/5	1	1	1	1	1

AHP Method as Weighting Counter

1. Normalize the pairwise comparison which represents the rate of preference of each respondent.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

where: $\bar{a}_{ij}$ = Normalized Pairwise Comparison Matrix

a_{ij} = Value in Pairwise Comparison Matrix

n = Number of Criterion

Based on equation (1) and the result values of the matched pairwise matrix are as shown in Table 6 below.

Table 6. Normalized Pairwise Comparison Matrix

	MAT	**CSC**	**ISP**	**STA**	**QMT**	**ICT**	**ACC**	**ECO**	**DSC**	**ITT**
MAT	0.357	0.217	0.179	0.264	0.670	0.227	0.321	0.217	0.227	0.227
CSC	0.071	0.043	0.036	0.053	0.022	0.045	0.013	0.043	0.045	0.045
ISP	0.071	0.043	0.036	0.009	0.022	0.045	0.013	0.043	0.045	0.045
STA	0.071	0.043	0.214	0.053	0.022	0.227	0.013	0.217	0.227	0.227
QMT	0.071	0.261	0.214	0.316	0.134	0.227	0.321	0.261	0.227	0.227
ICT	0.071	0.043	0.036	0.011	0.027	0.045	0.064	0.043	0.045	0.045
ACC	0.071	0.217	0.179	0.264	0.027	0.045	0.064	0.043	0.045	0.045
ECO	0.071	0.043	0.036	0.011	0.022	0.045	0.064	0.043	0.045	0.045
DSC	0.071	0.043	0.036	0.011	0.027	0.045	0.064	0.043	0.045	0.045
ITT	0.071	0.043	0.036	0.011	0.027	0.045	0.064	0.043	0.045	0.045

2. Find the sum of each column from the same row based on the normalized matrix to calculate the weight of synthesis (Cahyapratama and Sarno, 2018).

$$\sum column = k1 + k2 + k3 + \cdots + kn \quad (2)$$

where: k = Value in column from the same row

Based on equation (2), the result of the weight of synthesis are as in Table 7.

Table 7. Weight of Synthesis

Criteria	**Weight Synthesis**
MAT	2.906091141
CSC	0.418329034
ISP	0.374392303
STA	1.316268051
QMT	2.260057454
ICT	0.431896109
ACC	1.001741867

ECO	0.427431823
DSC	0.431896109
ITT	0.431896109

3. Calculate the eigenvalues by multiplying each of the matched matrix columns from the same row, then lift it by total criterion (Cahyapratama and Sarno, 2018).

$$\lambda_1 = (k1 \times k2 \times k3 \times \ldots \times kn)^{\frac{1}{n}} \tag{3}$$

where: λ = Eigenvalue

n = Number of Criterion

Table 8 shows the eigenvalue calculated from equation (3) with the sum of the eigenvalues.

Table 8. Eigenvalue

Criteria	**Eigenvalue**
MAT	4.256699613
CSC	0.605885939
ISP	0.506495684
STA	1.379729661
QMT	3.318573963
ICT	0.617033863
ACC	1.174618943
ECO	0.605885939
DSC	0.617033863
ITT	0.617033863
Sum	13.69899133

4. The weight of criterion for each criterion then divides the eigenvalues of each criterion with the total number of eigenvalues (Cahyapratama and Sarno, 2018).

$$weight\ of\ criterion = \frac{\lambda}{\sum \lambda} \tag{4}$$

By using equation (4), Table 9 below shows the weight of each criterion.

Table 9. Weight of Criterion

Criteria	**Weight of Criterion**
MAT	0.310730879
CSC	0.044228507
ISP	0.03697321
STA	0.10071761
QMT	0.242249512
ICT	0.045042284
ACC	0.085744922

ECO	0.044228507
DSC	0.045042284
ITT	0.045042284

5. Next, divide the weight of synthesis with the weight of criterion to determine the importance value for each criterion (Cahyapratama and Sarno, 2018).

$$importance\ value = \frac{weight\ of\ synthesis}{weight\ of\ criterion} \tag{5}$$

Based on equation (5), the importance value of each criterion calculated and the result as shown in Table 10.

Table 10. Importance Value

Criteria	**Importance Value**
MAT	9.352437561
CSC	9.458357485
ISP	10.12604267
STA	13.06889685
QMT	9.329461333
ICT	9.58868129
ACC	11.68281273
ECO	9.664170205
DSC	9.58868129
ITT	9.58868129

6. After that, divide the sum of importance values with the number of criterions to obtain the highest eigenvalue (λ_{max}) (Cahyapratama and Sarno, 2018).

$$\lambda_{max} = \frac{\sum important\ value}{n} \tag{6}$$

where: λ_{max} = Maximum Eigenvalue

After using equation (6), the maximum eigenvalue is 10.14482227.

7. Obtain the consistency index (CI) to ensure that decision-making judgment is consistent (Cahyapratama and Sarno, 2018).

$$CI = \frac{(\lambda_{max} - n)}{n} \tag{7}$$

where: CI = Consistency Index

The CI obtained by using equation (7) in order to ensure that the decision-making judgement is consistent resulting in the value of 0.014482227.

8. Check the hierarchy's consistency with the condition that if the consistency ratio (CR) is less than or equals to 0.1, the calculated result is assumed true (Cahyapratama and Sarno, 2018). The values of IR are as shown in Table 11.

$$CR = \frac{CI}{IR} \tag{8}$$

Where: CR = Consistency Ratio

IR = Index Random Consistency

Table 11. Index Random Consistency

Matrix	1	2	3	4	5	6	7	8	9	10	11	12
IR	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Then the CR derived using equation (8) resulting in the value of 0.009719616. Since the value of CR is less than 0.1, the result of this calculation can be assumed to be true and the calculation can be proceeded.

<u>SAW Method to Rank the Alternatives</u>

1. The normalization of the matrix is customized to the type of criterion, resulting in a normalized matrix (Setyani and Saputra, 2016).

$$r_{ij} = \frac{x_{ij}}{max_i} \tag{9}$$

Where: r_{ij} = Normalized Matrix [i][j]

x_{ij} = Decision Matrix [i][j]

i = 1, 2, 3, …, m

j = 1, 2, 3, …, n

max_i = The Highest value of matrix column

From the decision matrix in Table 3, the result of the normalization based on equation (9) as in Table 12.

Table 12. Normalized Decision Matrix

	Criteria									
Alternatives	MAT	CSC	ISP	STA	QMT	ICT	ACC	ECO	DSC	ITT
CS230	0.125	1	0	0.5	0	1	0	0	0	0.5
CS247	1	0.238	0	0.5	0.333	0	0	0	0	0
CS248	0.812	0.047	0.071	1	1	0	0.5	1	0.5	0
CS249	1	0.047	0.071	1	0.333	0	1	1	0.5	0
CS264	0.125	0.238	1	0.5	0	0.666	0.5	0	0	0.5
CS267	0.875	0.142	0.214	1	0.333	0.333	0	1	1	0
CS270	0.125	0.714	0.357	0.5	0	0.333	0	0	0	1

2. Then, calculate the final alternative value (Cahyapratama and Sarno, 2018).

$$v_i = \sum_{j=1}^{n} w_i r_{ij} \tag{10}$$

Where: v_i = Final value of the Alternative

w_i = Weight of Criterion

r_{ij} = Normalized Value

The final value calculated using equation (10) and the result as in Table 13.

Table 13. Final Alternative Value

Alternatives	Final Value
CS230	0.200992099
CS247	0.452370118
CS248	0.709805134
CS249	0.64943996
CS264	0.232125764
CS267	0.571883041
CS270	0.194053053

3. List out the rankings based on the value of each alternative ranking in descending order to determine the best selection outcome (Cahyapratama and Sarno, 2018). The rankings are as shown in Table 14.

Table 14. Alternative Ranking

Alternatives	Rank
CS230	6
CS247	4
CS248	1
CS249	2
CS264	5
CS267	3
CS270	7

The first ranked alternative is CS248 which is matched with the respondent's current degree program. This implementation then repeated for all seventy respondents with various criteria preferences.

The Accuracy of AHP-SAW Method

After all the respondents' data has been calculated using the Microsoft Excel software template, the result of their first ranked alternative and current degree program is summarized in Table 15 below.

Table 15. Result Comparison

Current Degree Program	**Respondent**	**First Ranked Alternative**	**Comparison**
CS230	1	CS230	Matched
	2	CS230	Matched
	3	CS230	Matched
	4	CS230	Matched
	5	CS230	Matched
	6	CS230	Matched
	7	CS230	Matched
	8	CS230	Matched
	9	CS230	Matched
	10	CS230	Matched
CS247	11	CS247	Matched
	12	CS247	Matched
	13	CS247	Matched
	14	CS247	Matched
	15	CS247	Matched
	16	CS247	Matched
	17	CS247	Matched
	18	CS247	Matched
	19	CS248	Unmatched
	20	CS267	Unmatched
CS248	21	CS248	Matched
	22	CS248	Matched
	23	CS248	Matched
	24	CS248	Matched
	25	CS248	Matched
	26	CS248	Matched
	27	CS248	Matched
	28	CS248	Matched
	29	CS248	Matched
	30	CS249	Unmatched
CS249	31	CS249	Matched
	32	CS249	Matched
	33	CS249	Matched
	34	CS249	Matched
	35	CS249	Matched
	36	CS249	Matched
	37	CS249	Matched
	38	CS249	Matched
	39	CS249	Matched
	40	CS249	Matched

CS264	41	CS264	Matched
	42	CS264	Matched
	43	CS264	Matched
	44	CS264	Matched
	45	CS264	Matched
	46	CS264	Matched
	47	CS264	Matched
	48	CS264	Matched
	49	CS264	Matched
	50	CS264	Matched
CS267	51	CS267	Matched
	52	CS267	Matched
	53	CS267	Matched
	54	CS267	Matched
	55	CS267	Matched
	56	CS267	Matched
	57	CS267	Matched
	58	CS267	Matched
	59	CS267	Matched
	60	CS267	Matched
CS270	61	CS270	Matched
	62	CS270	Matched
	63	CS270	Matched
	64	CS270	Matched
	65	CS270	Matched
	66	CS270	Matched
	67	CS270	Matched
	68	CS270	Matched
	69	CS230	Unmatched
	70	CS230	Unmatched
Total Matched Comparison			65

During this stage, the accuracy level is obtained by comparing the generated first-ranked alternative from the AHP and SAW method with the actual data which is the alternative that has been selected by the respondents. The accuracy rate calculation are as follows:

$$accuracy = \frac{number\ of\ matched\ comparison}{number\ of\ respondents} \times 100\% \tag{11}$$

From Table 15, there are 65 respondents with the result of the first ranked alternative that match with their current bachelor's degree program. This value can be used to identify the accuracy of this methods by using equation (11) and the rate of accuracy is 92.85%.

3. Results and Discussion

There are three objectives of this research, the outcome for the first and second objective were various depending on the preference of each respondent, so the analysis will be based on one of the respondents' data. This specific respondent's current degree course is CS248.

The first objective is to use AHP to generate the weight of each criterion. In this method, from the rate of preference of each course code (criteria) collected by questionnaire given to the respondent then formed into a decision matrix. This decision matrix is then used in this method in finding the weight of criterion as further explained in the previous section. Table 16 below shows the result for weight of criterion of this respondent.

Table 16 Result of First Objective

Criteria	Weight of Criterion
MAT	0.310730879
CSC	0.044228507
ISP	0.03697321
STA	0.10071761
QMT	0.242249512
ICT	0.045042284
ACC	0.085744922
ECO	0.044228507
DSC	0.045042284
ITT	0.045042284

From the above result, this respondent's highest criteria weight's value is MAT which is 0.310730879, followed by QMT with the value of 0.242249512, STA with the weight of 0.10071761 and others. These values mean that this respondent found that these three criteria are the most preferred than the other criteria. This information is crucial for the next calculation in the SAW method since these values will be affecting the ranking of the alternatives.

The second objective is to rank the best selection of bachelor's degree programs based on multiple criteria using the SAW method. In this method, each alternative has their own criteria's value. The values are derived from the total of courses offered by each alternative. The values were then formed in matrix and used in SAW method calculation together with the weight of criterion derived by AHP method previously. The result of the alternative ranking is as shown in Table 17.

Table 17. Result of Second Objective

Alternatives	Rank
CS230	6
CS247	4
CS248	1
CS249	2
CS264	5
CS267	3
CS270	7

From the above result, the result of the first rank alternative from this calculation is CS248. This result is related to the previous objective's result because as in Table 3, the alternative of CS248 has the highest criteria value in MAT, QMT and STA which goes the same way as this respondent's preference in the previous discussion. This result also matches with the actual bachelor's degree program studied by this respondent which is CS248. This shows that the respondent's preference is taken seriously in research calculation, resulting in an accurate outcome as a testimony.

The last objective of this research is to calculate the accuracy of the best bachelor's degree program selected using AHP-SAW method by comparing it with the actual bachelor's degree program studied by each student. 65 out of 70 respondents' first rank alternative and actual bachelor's degree program are matched as shown in Figure 1. These numbers result in 92.85% of accuracy for these methods and can be assumed as reliable to be implemented for anyone to make a similar decision.

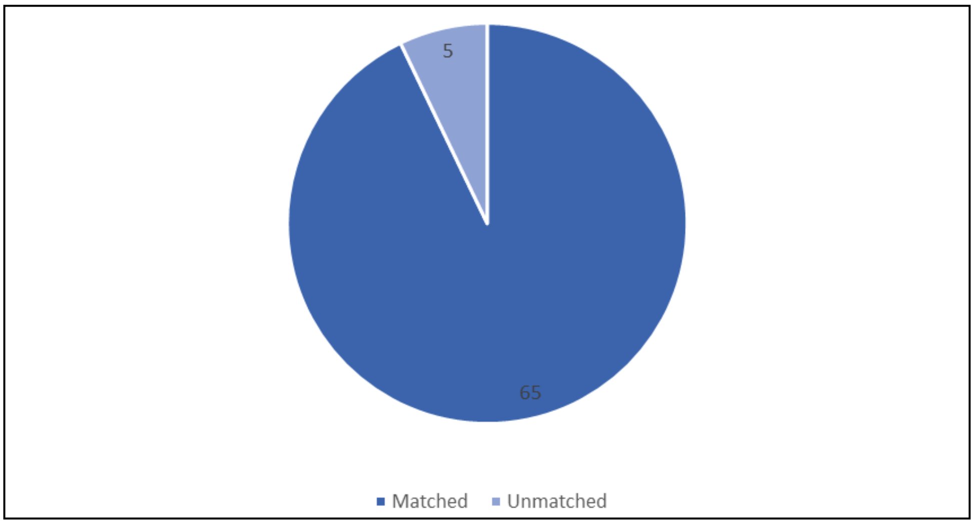

Figure 1. Result Comparison for Third Objective

4. Conclusion and Recommendation

MCDM consists of various methods including AHP and SAW which was hybridized and implemented in this research to rank some of the degree courses from Faculty of Computer and Mathematical Science (FSKM) in Universiti Teknologi MARA (UiTM). This research was held to help students to make a decision on which bachelor's degree program is the most suitable for them based on their preference of the courses offered. In this research, the template of these methods can be customized according to the respondents' preference.

There are three objectives in this research that need to be achieved. All the objectives have been accomplished in this research successfully. The weight of each criteria can be customized based on individual preference which makes the AHP method flexible for anyone. The rank of alternatives that results from the SAW method also can be used to determine first, second and the next best choice for the decision-making. Based on the accuracy of this hybrid method, it can be concluded that these methods are reliable to be used and applied in real life situations.

The hybrid of AHP-SAW methods has been used successfully to achieve the goal of this research. Aside from this method, TOPSIS, ANP, and MAUT can also be used to select the best degree program based on one's preference. The results shown may differ if the other MCDM method was used. Other models of MCDM methods can be used for this problem in future studies, and the results of this study and the future studies can be compared. Finally, there are numerous methods that can be used to solve various types of problems.

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