Proceedings of Science and Mathematics
Faculty of Science, Universiti Teknologi Malaysia

Vol. 11, 2022, page 26 - 35

Ranking of the Best Internet Plans by Using Multi Criteria Decision Making Methods

Norsaidatulain Asral, Wan Rohaizad Wan Ibrahim*
Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia
*Corresponding author: wrohaizad@utm.my

Abstract
The internet has become one of the most powerful tools that people use these days in their daily life activities. The internet has changed the way people live and how they relate to each other. It has become the tools that people cannot live without. There are lots of things people can do with it. In this study, selection of the best internet plans to purchase will be discussed in detail. The main objective of this thesis is to rate the internet plans according to student's preferences as one of the types of internet plans' that are consumers by using two Multiple Criteria Decision Making (MCDM) methods. Analytic Hierarchy Process (AHP) method and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method are the two methods that will be discussed in detail in this thesis. These methods are able to help decision makers by developing pair-wise comparison judgments. This study has applied four criteria for selecting the best one among four internet plans. The selection criteria are availability, speed, type of connection and price/cost. By applying these two methods, Plan 1 should be selected as the best internet plans since it has won in many aspects according to all the criteria. Microsoft Excel is used to assist in accomplishing the calculation involved.

Keywords: AHP is most popular multicriteria methods.

1. Introduction

Operational research is the process of making better decisions through data analysis, mathematical modelling, optimization, and other analytic methods. The internet is the worldwide used among people to do daily activities such as in communication, study, working, business, and many other activities. The internet is the global system of interconnected computer networks that uses the internet protocol suite to communicate between networks and devices. In this competitive world, there are many types of brands and services that provide different types of convenience to many people. As a user, we can be the decision maker to choose the best choices when purchase the internet plans. As decision maker we need to consider a lot of criteria that may be helps us to find the best internet plans.

There are some important criteria for a decision maker need to consider before choosing internet plans such as the availability of internet plans at their place, type of internet connection, speed of internet plans, prices, and brands. Multi-criteria decision making (MCDM) is an advanced field of Operations Research which deals with complex decision problems involving multiple criteria, goals, or objectives of conflicting nature. The tools and methodologies provided by MCDM include some mathematical models aggregating criteria and points of view or attributes.

Multi-Criteria Decision Making (MCDM) is a technique of figuring out the most suitable or the best chosen in line with the selected standards. Because the criteria basically battle with each other, there is no single solution that satisfies all the standards simultaneously. MCDM technique has its advantage which are they can compare the wide variety of the standards and alternatives. (Yildiz and Ergul,2015).

2. Literature Review

2.1. Multi Criteria Decision

Multi-criteria decision making (MCDM) is a branch of Operations Research (OR). In a MCDM problem, the basic ingredients are the criteria and alternatives. Different alternatives evaluated against set criteria to formulate a comparison of alternatives. The results can be improved further by assigning weights to different criteria, as the importance can vary extremely from one decision-maker to another. Hence, for selected criteria, there can be a different level of importance from the perspective of different decision-makers (Sabaei et al., 2015). It is important to evaluate the assigned weights to each criterion from different decision-makers to ensure the reliability of results.

2.2. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is one of the most popular and widely employed multicriteria methods. The technique for this method is by rating alternatives and aggregating to find the most relevant or the best alternatives are integrated (Ramanathan,2004). The main difference between this AHP method and other MCDM methods is the major characteristic of AHP is the use of pairwise comparison. The pairwise comparison used to estimate criteria weight and to compare the alternatives with the different criteria.

For the internet plans, AHP can be used to classify the preferences of consumers and market sales. The availability and speed of the internet plans will be the main criteria. Through measuring the average of criteria and alternatives, the weight was derived from the criteria and revealed the best alternative.

AHP developed by Saaty (1980), uses pairwise comparison questions to elicit a matrix of judgments of the relative preference between each pair of alternatives with respect to each attribute, and a matrix of judgments of the relative importance of each pair of attributes.

2.3. Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)

The parametric optimization of machining performance at different combinations has been evaluated through a multi-criteria optimization technique named as ‘TOPSIS’ which was developed by researchers in 1981 and further modified in two stages during 1987 as well as 1993. Among the different possible MCDM methods, TOPSIS has some unique features, such as that of being particularly suitable for application when ranking many alternatives due to its simplicity, good computational efficiency and rationality (Roszkowska, 2011). The basic concept for TOPSIS method is to choose the best alternative depending on closest and most distance respectively to positive ideal solution and negative ideal solution.

2.4. Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE)

The PROMETHEE belongs to the family of outranking methods and is used around the world in a wide variety of decision scenarios such as business, governmental institutions, transportation, healthcare and education. The PROMETHEE method helps decision makers find the alternative that best suits their goal and their understanding of the problem. The basic elements of the PROMETHEE method were first introduced by Professor Jean-Pierre Brans in 1982. It was later developed and implemented by Professor Jean-Pierre Brans and Professor Mareschal in 1994.

3. Methodology

3.1. Research Data

The concept for this study is to find the best internet plans by using four different main criteria that will be considered. There are a lot of well-known brands of internet plans. A survey will be conducted without mentioning what type of brands the alternatives will be.

3.2. Data Collection

In this study, the understanding that needs to be seized from the experts is the standards for the selection of internet plans of every criterion for choice plans. Survey forms are the approach that can be used in this research. The useful statistics for internet plan selection can be obtained by using the evaluation of raw data on features from various brands of internet plans and references from many sources.

In this study, student of Department of Mathematics at Faculty of Science, UTM who without knowing the brand of the selection of internet plans as the specialists which have been asking to fill in the survey form to gain the useful facts about the criteria of choosing internet plans as a user.

3.3 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) can help to solve the complex problems with the structure of the hierarchy of criteria, stakeholders, and outcomes considered by developing weights or priorities. The structure of an AHP model is a model of an inverted tree. Where, there is a single objective or purpose of the problem of decision making at the top.

3.4 Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS)
In this method, two artificial alternatives are hypothesized:

i. Ideal alternative: The one which has the best level for all attributes considered.
ii. Negative ideal alternative: The one which has the worst attribute values.

Here, TOPSIS selects the alternative that is the closest to the ideal and farthest from the negative ideal alternative.

4. Results and discussion

4.1. Analytic Hierarchy Process (AHP) Analysis
The pair-wise comparison for each criterion is formed by comparing the scales from the rating process of 100 respondents. From the evaluation in the survey, the scale of the criteria will be rated. The pairwise comparison for each criterion is formed by comparing the scales from the rating process of 100 respondents. From the evaluation in the survey, we will rate the scale of criteria.
The pair-wise comparison table of each criteria when developed into a square matrix with diagonal elements in the matrix are 1 as shown as in Table 1.

Table 1 Pair-wise Comparison Matrix for Four Selection Criteria

Criteria	Availability	Speed	Type of Connection	Price
Availability	1.0000	5.0000	9.0000	6.0000
Speed	0.2000	1.0000	5.0000	2.0000
Type of Connection	0.1111	0.2000	1.0000	0.3333
Price	0.1667	0.5000	3.0000	1.0000

From Table 1, Availability possesses the highest importance in all criteria, followed by Speed. Next is Price and the lowest importance is Type of Connection. After finishing constructing the pairwise comparison, calculate the priority of criteria. By using the formula of AHP method, the best criteria of internet plan was obtained.

Table 2 Develop the Weights for the Criteria

Criteria	Availability	Speed	Type of Connection	Price	4th root of product	Priority Vector(PV)
Availability	1.0000	5.0000	9.0000	6.0000	4.0536	0.6493
Speed	0.2000	1.0000	5.0000	2.0000	1.1892	0.1905
Type of Connection	0.1111	0.2000	1.0000	0.3333	0.2934	0.0470
Price	0.1667	0.5000	3.0000	1.0000	0.7071	0.1133
SUM	1.4778	6.7000	18.0000	9.3333	6.2433	1.0000
SUM*PV	0.9595	1.2762	0.8458	1.0571	4.1386	
Lambda max	4.1386					
Consistency Index,*CI*	0.0462					
Consistency Ratio, *CR*	0.0513					

From Table 2 below shown the values of the weights, *W* for every criterion also known as Priority Vector in this research. The steps on how to get all the values will be explained below.

First, calculate the 4th roots of the product since in this study we had four criteria as below.

$$\begin{aligned} \text{Availability} &= \sqrt[4]{1 \times 5 \times 9 \times 6} \\ &= 4.0536 \\ \text{Speed} &= \sqrt[4]{0.2 \times 1 \times 5 \times 2} \\ &= 1.189 \\ \text{Type of Connection} &= \sqrt[4]{0.1111 \times 0.2 \times 1 \times 0.3333} \\ &= 0.2934 \\ \text{Price} &= \sqrt[4]{0.1667 \times 0.5 \times 3 \times 1} \\ &= 0.7071 \end{aligned}$$

Each of the aforementioned fourth root of product values are then added together to equal 6.2433. Secondly, calculate the weight of the criteria.

$$\begin{aligned} \text{Availability} &= \left(\frac{4.0536}{6.2433}\right) \\ &= 0.6493 \\ \text{Speed} &= \left(\frac{1.1892}{6.2433}\right) \\ &= 0.1905 \\ \text{Type of Connection} &= \left(\frac{0.2934}{6.2433}\right) \\ &= 0.0470 \\ \text{Price} &= \left(\frac{0.7071}{6.2433}\right) \\ &= 0.1133 \end{aligned}$$

Note that, the sum of weights for each criterion must be equal to 1. Next, we calculate and check the consistency ratio (*C.R*). The pairwise comparison values in each column are added together. Each sum is then multiplied by the respective weight, *W*.

Note the row labelled “SUM*PV” shown in Table 4.2 above. Each value in this row shows the result of multiplying the respective sum by the respective weight for each criterion. The aforementioned values “SUM*PV” added together to yield a total 4.1386, this value known as Eigenvalue (λ_{max}).

The Consistency Index (*C.I*) is calculated by using this formula:

$$C.I = \left(\frac{\lambda_{max} - n}{n - 1}\right)$$

n is the number of criteria being compared.

The Consistency Ratio (*C.R*) is calculated by dividing the (*C.I*) with a Random Index (*R.I*) based on Table 3.1. The (*R.I*) is a direct function of the number of criteria being considered. Since our n is 4, the (*R.I*) we used is 0.900.
In general, the Consistency Ratio (*C.R*) is calculated as:

$$= \frac{C.I}{R.I}$$
$$= \frac{0.0462}{0.900}$$
$$= 0.0513$$

If the *C.R* ≤ 0.10, the decision maker's pairwise comparisons are relatively consistent. In our case, the CR equals 0.0513, means our pairwise comparisons are relatively consistent and no corrective action is necessary. But, if the *C.R* > 0.10, we must consider re-evaluating out pairwise comparisons. Resolved and the analysis need to be re-done again.

Next, we need to develop the ratings for each decision alternative for each criterion. There will be one pair-wise comparison matrix for each criterion. And within each matrix, the pairwise comparisons will rate each internet plan relative to every other plan. So, we have four separate matririces since we have four criteria applicable to our internet plans decision which are availability, speed, type of connection and price. Our matrix must be of size 4×4. Here are the four matrices to determine the ratings for each decision alternative (internet plans) for each criterion.

Table 3 Availability of Internet Plans

1.Availability						
	Plan 1	**Plan 2**	**Plan 3**	**Plan 4**	**4th root of product**	**Priority Vector(W)**
Plan 1	1.0000	3.0000	3.0000	4.0000	2.4495	0.5150
Plan 2	0.3333	1.0000	1.0000	2.0000	0.9036	0.1900
Plan 3	0.3333	1.0000	1.0000	2.0000	0.9036	0.1900
Plan 4	0.2500	0.5000	0.5000	1.0000	0.5000	0.1051
SUM	1.9167	5.5000	5.5000	9.0000	4.7567	1.0000
SUM*PV	0.9870	1.0448	1.0448	0.9460	4.0226	
Lambda max	4.0226					
Consistency Index,*C.I*	0.0075					
Consistency Ratio, *C.R* (0.9)	0.0084					

Concerning Availability based on Table 3,

- Respondents determine that availability for Plan 1 is "moderately important" (3) to Plan 2 and Plan 3. While "intermediate value between moderate to strong important" (4) to Plan 4. Then for Plan 2 is "equal important" (1) and "intermediate value between equal to moderate important" (2) to Plan 3 and Plan 4 respectively. Lastly, Plan 3 is "intermediate value between equal to moderate important" (2) to Plan 4.

Table 4 Speed on download and upload of internet plans

2.Speed						
	Plan 1	**Plan 2**	**Plan 3**	**Plan 4**	**4th root of product**	**Priority Vector (W)**
Plan 1	1.0000	3.0000	0.3333	5.0000	1.4953	0.2634
Plan 2	0.3333	1.0000	0.2000	3.0000	0.6687	0.1178
Plan 3	3.0000	5.0000	1.0000	7.0000	3.2011	0.5638
Plan 4	0.2000	0.3333	0.1429	1.0000	0.3124	0.0550
SUM	4.5333	9.3333	1.6762	16.0000	5.6776	1.0000
SUM*PV	1.1940	1.0993	0.9451	0.8804	4.1187	
Lambda max	4.1187					
Consistency Index, *C.I*	0.0396					
Consistency Ratio, *C.R* (0.9)	0.0440					

Concerning Speed based on Table 4,

- Respondents determined that speed for Plan 1 are "moderately important" (3) to Plan 2 and "strong important" (5) to Plan 4. Then for Plan 2 is "moderate important" (3) to Plan 4. Lastly, Plan 3 is "moderate important" (3), "strong important" (5) and "very strong important" (7) to Plan 1, Plan 2 and Plan 4 respectively.

Table 5 Type of connection for internet plans

3.Type of Connection						
	Plan 1	Plan 2	Plan 3	Plan 4	4th root of product	Priority Vector (W)
Plan 1	1.0000	1.0000	0.3333	0.2500	0.5373	0.1142
Plan 2	1.0000	1.0000	0.5000	0.3333	0.6389	0.1358
Plan 3	3.0000	2.0000	1.0000	0.5000	1.3161	0.2797
Plan 4	4.0000	3.0000	2.0000	1.0000	2.2134	0.4704
SUM	9.0000	7.0000	3.8333	2.0833	4.7057	1.0000
SUM*PV	1.0276	0.9505	1.0721	0.9799	4.0301	
Lambda max	4.0301					
Consistency Index, $C.I$	0.0100					
Consistency Ratio, $C.R$ (0.9)	0.0111					

Concerning Type of Connection based on Table 5,

- Respondents determine that type of connection for Plan 1 is "equally important" (1) to Plan 2 and Plan 3. While "intermediate value between moderate to strong important" (4) to Plan 4. Then for Plan 3 is "moderate important" (3) and "intermediate value between equal to moderate important" (2) to Plan 1 and Plan 2 respectively. Lastly, Plan 4 is "intermediate value between moderate to strong important" (4), "moderate important" (3) and "intermediate value between equal to moderate important" (2) to Plan 1, Plan 2 and Plan 3 respectively.

Table 6 Price for internet plans

4.Price						
	Plan 1	Plan 2	Plan 3	Plan 4	4th root of product	Priority Vector (W)
Plan 1	1.0000	0.2000	1.0000	1.0000	0.6687	0.1278
Plan 2	5.0000	1.0000	4.0000	5.0000	3.1623	0.6042
Plan 3	1.0000	0.2500	1.0000	2.0000	0.8409	0.1607
Plan 4	1.0000	0.2000	0.5000	1.0000	0.5623	0.1074
SUM	8.0000	1.6500	6.5000	9.0000	5.2343	1.0000
SUM*PV	1.0221	0.9968	1.0442	0.9669	4.0301	
Lambda max	4.0301					
Consistency Index, $C.I$	0.0100					
Consistency Ratio, $C.R$ (0.9)	0.0111					

Concerning Price (from questionnaire's result),

- Respondents determine that the price for Plan 1 is "equally important" (1) to Plan 3 and Plan 4. Then for Plan 2 is "intermediate value between moderate to strong important" (4) and "strong important" (5) to Plan 3 and Plan 4 respectively. Lastly, Plan 3 is "equal important" (1) and "intermediate value between equal to moderate important" (2) to Plan 1 and Plan 4.

The "equal important" (1) values shown along the upper-left to lower-right diagonal are comparing each plan to itself and so, by definition must be equal to one. The remaining values shown in the matrix represent the reciprocal pairwise comparisons of the relationship. The process to calculate the rating for each criterion was the same with the process to calculate the ($C.R$) before.
All the ($C.R$) for all four of the aforementioned matrices depicting the rating for each decision alternative for each criterion are ≤ 0.10. Therefore, no correction actions are necessary.

For the final phase based on Table 7, we calculate the weighted average rating for each decision alternative where we can choose the best internet plan that has the highest score.

We determine the final scores for each internet plans by multiplying the criteria weight (from first step) by rating for the decision internet plan for each criterion and summing the respective products. Here based on Table 8, we can see that Plan 1 is the best plan because it possesses the highest score at 0.4044. By using this AHP method, we can conclude that the arrangement of the internet plans from highest to lowest scores is Plan 1> Plan 3> Plan 2> Plan 4.

Table 7: Weighted average rating each decision alternatives

Weighted Average Rating Each Decision Highest						Ranking
	Availability	Speed	Type of Connection	Price	Score	
	0.6493	0.1905	0.0470	0.1133	1.0000	
Plan 1	0.5150	0.2634	0.1142	0.1278	0.4044	
Plan 2	0.1900	0.1178	0.1358	0.6042	0.2206	
Plan 3	0.1900	0.5638	0.2797	0.1607	0.2621	
Plan 4	0.1051	0.0550	0.4704	0.1074	0.1130	:P1>P3>P2>P4
	1.0000	1.0000	1.0000	1.0000	1.0001	

4.2. The TOPSIS Model for Internet Plans Selection

In this method two artificial alternatives are hypothesized:

1. Ideal alternative, A*: The one which has the best level for all attributes considered.
2. Negative ideal alternative, A': The one which has the worst attribute values.

TOPSIS selects the alternative that is the closest to the ideal solution and farthest from the negative ideal alternative.

Table 4.8 shows the decision matrix with weights obtained from AHP method as input to TOPSIS method.

Table 8 The decision matrix with weights

Step 1(a)				
Weight, *W*	0.6493	0.1905	0.0470	0.1133
	Availability	**Speed**	**Type of Connection**	**Price**
Plan 1	0.5150	0.2634	0.1142	0.1278
Plan 2	0.1900	0.1178	0.1358	0.6042
Plan 3	0.1900	0.5638	0.2797	0.1607
Plan 4	0.1051	0.0550	0.4704	0.1074

Starting with construct normalized decision matrix.

$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \quad i = 1,2,3,4 \; ; \; j = 1,2,3,4.$

This step transforms various attribute dimensions into non-dimensional attributes, which allows comparison across criteria, based on Table 9 and 40.

Table 9 Transforms various attribute dimensions into non-dimensional attributes

Weight, *W*	0.6493	0.1905	0.0470	0.1133
	Availability	**Speed**	**Type of Connection**	**Price**
Plan 1	0.5150	0.2634	0.1142	0.1278
Plan 2	0.1900	0.1178	0.1358	0.6042
Plan 3	0.1900	0.5638	0.2797	0.1607
Plan 4	0.1051	0.0550	0.4704	0.1074
x_{ij}^2	0.3484	0.4042	0.3309	0.4187
$(\sum x_{ij}^2)^{\frac{1}{2}}$	0.5903	0.6357	0.5753	0.6470

Based on Table 4.9, to get normalized decision matrix, by using this formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \; for\ i = \ 1,2,3,4\ ;\ j = 1,2,3,4.$$

Table 10 Normalized decision matrix

	Step 1(b) : r_{ij}			
Weight, *W*	0.6493	0.1905	0.0470	0.1133
	Availability	**Speed**	**Type of Connection**	**Price**
Plan 1	0.8724	0.4143	0.1985	0.1975
Plan 2	0.3218	0.1853	0.2360	0.9337
Plan 3	0.3218	0.8869	0.4862	0.2483
Plan 4	0.1781	0.0865	0.8176	0.1660

Next, multiply each column for Plan 1 until Plan 4 in Table 4.10 by its associated weights, *W* to get an element of the new matrix is $v_{ij} = w_j r_{ij}$ (Table 4.11).

Table 11: The weighted normalized decision matrix.

	Step 2(a) : v_{ij}				A*:Ideal Solution
Weight, *W*	0.6493	0.1905	0.0470	0.1133	A' : -ve Ideal Solution
	Availability	**Speed**	**Type of Connection**	**Price**	
Plan 1	0.5665	0.0789	0.0093	0.0224	
Plan 2	0.2090	0.0353	0.0111	0.1058	
Plan 3	0.2090	0.1689	0.0229	0.0281	
Plan 4	0.1156	0.0165	0.0384	0.0188	

Based on Table 11, we identified the ideal solution (A*) and negative ideal solution (A') for each criterion. The green one is the ideal solution. For availability, speed and type of connection, the ideal solution is the highest scores between the plans. While for price, we choose the lowest score as the ideal solution because for price the less the better.

The orange one is the negative ideal solution for each criterion. For the negative ideal solution, the condition is opposite to the ideal solution. We will choose the lowest scores for availability, speed, and type of connection. And the highest score for price will be selected as a negative ideal solution.

Ideal solution, A* = {0.5665,0.1689,0.0111,0.0188}

Negative Ideal solution, A' = {0.1156,0.0165,0.0093,0.1058}

Next based on Table 12 and Table 13, we determine the separation from A* and separation from A' respectively by using formula as below:

Table 12 Separation from A*

$$S_i^* = \left(\sum \left(v_{ij} - v_j^*\right)^2\right)^{\frac{1}{2}}$$

$$S_i' = \left(\sum \left(v_{ij} - v_j'\right)^2\right)^{\frac{1}{2}}$$

	Step 3(a) : separation from A*					
Weight, *W*	0.6493	0.1905	0.0470	0.1133		
	Availability	**Speed**	**Type of Connection**	**Price**	Summation of Plan n row	$S_i^* = \left(\sum (v_{ij} - v_j^*)^2\right)^{\frac{1}{2}}$
Plan 1	0.0000	0.0081	0.0000	0.0000	0.0081	0.0901
Plan 2	0.1278	0.0179	0.0000	0.0076	0.1532	0.3915
Plan 3	0.1278	0.0000	0.0001	0.0001	0.1280	0.3578
Plan 4	0.2033	0.0232	0.0007	0.0000	0.2272	0.4767

Table 13 Separation from A'

Step 3(b) : separation from A'						
Weight, W	0.6493	0.1905	0.0470	0.1133		
	Availability	Speed	Type of Connection	Price	Summation of plan n row	$S_i' = \left(\sum (v_{ij} - v_j')^2\right)^{\frac{1}{2}}$
Plan 1	0.2033	0.0039	0.0000	0.0070	0.2141	0.4627
Plan 2	0.0087	0.0004	0.0000	0.0000	0.0091	0.0952
Plan 3	0.0087	0.0232	0.0002	0.0060	0.0382	0.1954
Plan 4	0.0000	0.0000	0.0008	0.0076	0.0084	0.0917

For the last step, we calculate the relative closeness to the ideal solution by using this formula. Relative closeness to the ideal solution, C_i^*

$$C_i^* = \frac{S_i'}{S_i^* + S_i'}$$

Table 4.14 The relative closeness to ideal solution.

Step 4 : Relative closeness to Ideal Solution		
	$C_i^* = \frac{S_i'}{S_i^* + S_i'}$	Ranking
Plan 1	0.8370	
Plan 2	0.1957	
Plan 3	0.3532	
Plan 4	0.1614	: P1>P3>P2>P4

After calculating and following all the steps, we can conclude and rank all the internet plans according to all criteria by looking how far and close to the ideal solution. In the TOPSIS method, the higher the relative closeness to the ideal solution, the higher the performance score.

From Table 4.14, we can see that Plan 1 has won since it has the highest value for relative closeness to the ideal solution compared to other plans. Hence, we can conclude the ranking sequences from the best selection to the worst selection as Plan 1> Plan 3> Plan 2> Plan 4.

Conclusion

Both methods, AHP and TOPSIS were considered both qualitative and quantitative approaches to study. The hierarchy structure of the main goal, criteria and the alternatives for internet plans are built in the first step. This is the most creative and important part or step of decision making.

I chose AHP method as one of the methods that I applied into this study because AHP method provides a rational framework for a needed decision by quantifying its criteria and every alternative option, and for relating those elements to achieve the main goal of the problem. AHP also converts this evaluation into numbers, which can be compared to all the possible criteria. By this we can prove that the AHP method is unique compared to other decision-making methods.

The TOPSIS method is selected to solve the problem in this study because TOPSIS is a method that has capacity and simplicity to solve a non-confined quantity of the alternatives and the criteria in the decision-making.

Acknowledgement

I would like to thank you and I wish the finest appreciation to my supervisors, Sir Wan Rohaizad bin Wan Ibrahim, for his guidance, encouragement and knowledge. His meaningful advice to me throughout this period will in no way be forgotten. I would like to thank Prof. Madya Dr. Zaitul Marlizawati as my examiner for all advice and support had given to me.

Much love and plenty of thanks I preferred to express to my beloved mother, Puan Norlela binti Ibrahim for all her love, care and support. For my siblings, many thanks for the best motivation. I am thus blessed to possess their love in my life. Finally, I would really like to express my honest appreciation to all my friends and coursemates for his or her willingness to assist and help me after I felt helpless.

References

[1] Abdullah, L., Chan, W., & Afshari, A. (2018). Application of promethee method for green supplier selection: A comparative result based on preference functions. *Journal of Industrial Engineering International*, *15*(2), 271–285. https://doi.org/10.1007/s40092-018-0289-z.

[2] Aminudin, N., Sundari, E., K, S., Deepalakshmi, P., ., F., Irviani, R., & Maseleno, A. (2018). Weighted product and its application to measure employee performance. *International Journal of Engineering & Technology*, *7*(2.26), 102. https://doi.org/10.14419/ijet.v7i2.26.14362.

[3] Analytic hierarchy process. (2011). *Multiple Attribute Decision Making*, 29–42. https://doi.org/10.1201/b11032-6.

[4] How consumers choose brands. (2010). *Creating Powerful Brands*, 89–139. https://doi.org/10.4324/9781856178501-12.

[5] Kobryń, A., & Prystrom, J. (2016). A data pre-processing model for the TOPSIS method. *Folia Oeconomica Stetinensia*, *16*(2), 219–235. https://doi.org/10.1515/foli-2016-003.

[6] Macharis, C., Springael, J., De Brucker, K., & Verbeke, A. (2004). Promethee and AHP: The design of operational synergies in Multicriteria Analysis. *European Journal of Operational Research*, *153*(2), 307–317. https://doi.org/10.1016/s0377-2217(03)00153-x.

[7] Mardani, A., Jusoh, A., MD Nor, K., Khalifah, Z., Zakwan, N., & Valipour, A. (2015). Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014. *Economic Research-Ekonomska Istraživanja*, *28*(1), 516–571. https://doi.org/10.1080/1331677x.2015.1075139.

[8] Millet, I., & Saaty, T. L. (1996). Selecting a synthesis mode in the analytic hierarchy process . *Proceedings of the International Symposium on the Analytic Hierarchy Process*. https://doi.org/10.13033/isahp.y1996.064.

[9] Sadeghzadeh, K., & Salehi, M. B. (2011). Mathematical Analysis of Fuel Cell Strategic Technologies Development Solutions in the automotive industry by the Topsis multi-criteria decision making method. *International Journal of Hydrogen Energy*, *36*(20), 13272–13280. https://doi.org/10.1016/j.ijhydene.2010.07.064.

[10] Supriyono, H., & Sari, C. P. (2018). Developing decision support systems using the weighted product method for House selection. *AIP Conference Proceedings*. https://doi.org/10.1063/1.5042905.

[11] Thakkar, J. J. (2021). Analytic Hierarchy Process (AHP). *Multi-Criteria Decision Making*, 33–62. https://doi.org/10.1007/978-981-33-4745-8_3.

[12] Wang, S., Sheng, Z., Xi, Y., Ma, X., Zhang, H., Kang, M., Ren, F., Du, Q., Hu, K., & Han, Z. (2018). The application of the analytic hierarchy process and a new correlation algorithm to urban construction and supervision using Multi-Source government data in Tianjin. *ISPRS International Journal of Geo-Information*, *7*(2), 50. https://doi.org/10.3390/ijgi7020050.

[13] Widianta, M. M., Rizaldi, T., Setyohadi, D. P., & Riskiawan, H. Y. (2018). Comparison of multi-criteria decision support methods (AHP, topsis, saw & promenthee) for employee placement. *Journal of Physics: Conference Series*, *953*, 012116. https://doi.org/10.1088/1742-6596/953/1/012116.

[14] Yildiz, A., & Ergül, E. U. (2015). A two-phased multi-criteria decision-making approach for selecting the best smartphone. *The South African Journal of Industrial Engineering*, *26*(3). https://doi.org/10.7166/26-3-1208.

[15] Zakeri, S., Ecer, F., Konstantas, D., & Cheikhrouhou, N. (2021). The vital-immaterial-mediocre multi-criteria decision-making method. *Kybernetes*. https://doi.org/10.1108/k-05-2021-0403.