THE BEST CHOICE OF ELECTRONIC DEVICES FOR ONLINE DISTANCE LEARNING (ODL) AMONG UNIVERSITI TEKNOLOGI MARA (UiTM) STUDENTS USING THE ANALYTICAL HIERARCHY PROCESS (AHP) METHOD

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ABSTRACT

The purpose of the paper is to determine the most preferable type of electronic device for online distance learning (ODL) among Universiti Teknologi MARA (UiTM) students using the Analytical Hierarchy Process (AHP) method, discover factors that lead the UiTM students to choose the preferable type of electronic device, and find the best choice of electronic devices for ODL using the AHP. What is the concern? Can a student buy an electronic device to ease and smooth the online study process? This paper wants to know what type of device gives the best choice compatible with the criteria that are reasonable and affordable. An approach to methodology is performed by using two analysis methods: qualitative and quantitative. A survey has been carried out to achieve the objectives of the study through a questionnaire. The data of 50 respondents has been recorded and used for the implementation of the AHP method. From the study, most of the respondents preferred laptops as the best device for ODL and put tablets as their last choice. The biggest factor that leads them to decide the best electronic device is its storage space. Meanwhile, the least affecting factor is the brand of device. Throughout the study, it proves that the AHP has a simpler process of decision-making and comes up with the desired result. Thus, it achieves the objectives of this study overall.

Keywords*: Analytical Hierarchy Process, Decision Making, Electronic Device, Qualitative Method, Quantitative Method*

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

1. Introduction

Electronic devices are highly in demand among students nowadays for online studies. Due to the pandemic of COVID-19 all around the world, our government needs to change the method of learning and teaching by using an online approach, likely to be called e-learning. The e-learning process has been accepted and is expected to grow further in the future. The impact of e-learning on students' academic performance is seen to be positive.

Apart from this, electronic devices have played a sufficiently great role in helping students with online studies and directly modernizing the global education system. Electronic devices can help to ease and smooth the e-learning process. According to the topic of research, the objectives are to examine the most preferable types of electronic devices for Online Distance Learning (ODL) among students of Universiti Teknologi MARA (UiTM), to determine the factors that lead the students of UiTM to choose the preferable type of electronic device, and to find the best choice of electronic device for ODL using the Analytical Hierarchy Process (AHP) method.

The Analytical Hierarchy Process (AHP) method is a mathematical tool for complex problem solving developed by Saaty in the late 1970s. The purpose is to calculate the weight of the criteria to evaluate the alternative solutions and come up with the best solution. The AHP method assists in decision-making of problems based on Multi-Criteria Decision Making (MCDM) and comes up with a unique solution or the best choice. This method divides a problem into three parts. First, the issue part that needs to be solved or the goal. Second, the possible solutions are called alternatives. Lastly, the most important part to apply the AHP is to evaluate the alternative solutions based on all the availability of criteria provided. AHP method is very flexible because it produces a simple way to find the relationship between criteria and alternatives (Lapevski, 2014).

In concept, the Analytical Hierarchy Process (AHP) method is very simple and easy to use for decision making. The AHP divides a problem into three parts. First, the issue part needs to be solved. Second, the possible solutions are called alternatives. Lastly, evaluate the alternative solutions based on all the criteria provided. There are five steps to using the AHP, which will be discussed in Methodology.

Many case studies out there have proven that the AHP approach helps large organizations achieve their strategic decisions or goals and come up with the best outcomes. Project prioritization is a difficult problem to solve in an organization. In 2015, BMC Medical Informatics and Decision-Making conducted research to find out the number of studies that applied the AHP in healthcare through a systematic literature review and evaluation of reporting. It finds that the number of studies applying the AHP has increased since 2005 in healthcare. However, the result states that the AHP has been applied inconsistently (Schmidt et al., 2015). In 2019, BMC Medical Research Methodology conducted research on health technology assessment (HTA) of optoelectronic biosensors for oncology by using the AHP method and Likert Scale. The purpose is to evaluate a new health technology to assay thyroglobulin in patients with differentiated thyroid cancer to improve its service from an organizational point of view. The result comes out and states that they do not need to improve the service because of the high satisfaction levels of the users (Improta et al., 2019).

2. Methodology/Implementation

The Analytical Hierarchy Process (AHP) provides a general theory of measurement for expressing both tangible and intangible factors (Wedley, 1990). In this research, the tangible or qualitative method has been applied by carrying out a questionnaire to collect the data involved. While the intangible or quantitative method is the calculation part of the implementation of the AHP. The data collection in the qualitative method part is performed to help with the development of the quantitative method.

2.1 Qualitative Method

The research has been conducted by using a questionnaire in order to apply the qualitative method. The respondents answer all the questions by evaluating each of the electronic devices' criteria to compare the level of importance for each criterion and the extent to which they are met by each alternative.

2.1.1 Instruments of The Research

The instruments chosen to conduct the research by using a questionnaire on a Google Form. The questionnaire is used to collect information from the respondents. It will be distributed to all students of UiTM randomly, and the data collection will be stopped once the target respondents are achieved.

The questionnaire will be answered online to meet the objectives of the research. The questionnaire consists of 3 sections. Section A is the background information of the respondents. Section B has one question to find the most preferable type of electronic device among students for online distance learning. Lastly, Section C is designed to determine the factors that lead the students to choose the preferable type of electronic device.

For Sections A and B, the respondents choose the answers based on the questions. In section C, the respondents need to answer the question based on the scale of the numbers given.

2.2 Quantitative Method

This research will use descriptive analysis to analyse the respondents' data. The data will be counted by using the Analytical Hierarchy Process (AHP) method in Microsoft Excel 2013. The analysed data is then converted into a percentage and presented in charts and graphs.

2.2.1 Data Analysis Method

Following is a list of all the phases involved during the implementation of the AHP. It shows the overall steps in a sequence flow. The objectives of study can be achieved by following each of the phases without leaving any behind.

Phase 1 Define the problem
Phase 2 The development of hierarchical framework
Phase 3 The AHP Algorithm
Step 1: Construct a pairwise comparison matrix
Step 2: Perform a pairwise comparison judgement
Step 3: The synthesis of pairwise comparison
Step 4: Check the consistency
Phase 4 Calculation of the weightage alternative
Phase 5 The development of overall priority ranking
Phase 6 Select the best alternative

2.3 Implementation

Phase 1 Define the problem
An Analytical Hierarchy Process (AHP) is a MCDM method for solving a complicated problem that happens to produce a unique result at the end of the process. It is a well-known approach that uses a hierarchical model with different levels of goals, criteria, and alternatives. If there is a defined hierarchy, the AHP can be expressed as a decision-making and estimation method that produces the percentage distribution of decisions according to the factors affecting the decision.

This idea arose from Saaty's previous and subsequent research on various topics. In 1977, they solved a particular problem in contingency planning and designed an alternative feature for the development of the country of Sudan. In 1979, they found an investment technology under uncertainty that dealing with terrorism in 1977, discovered an energy allocation and other smaller application in real life such as buying a car, choosing a job, and selecting a school which involved in a decision making (Oguztimur et al, 2015). Van Laarhoven and Pedyrycz proposed the earliest AHP method in 1983 in the study of fuzzy numbers with triangular membership function describe the fuzzy comparing judgement. Buckley discovered the fuzzy priorities of comparison ratios with trapezoidal membership functions in 1985. In 1989, Boender and his colleagues extended Van Laarhoven and Perdrycz's method and generate a sturdy approach to the normalization of the local priorities (Oguztimur et al, 2015).

Therefore, there are various applications of the AHP method that have been developed by many authors and have appeared in literature. Many of them are used by engineers, planners, lawyers, political scientists, mathematicians, and even normal citizens. It is undeniable that the AHP is easy to use and an understandable system of methods that provides pairwise comparisons in each area of expertise.

Phase 2 The development of hierarchical framework
In using the AHP to model a problem one needs a hierarchic or a network structure to represent that problem and pairwise comparisons to establish relations within the structure (Rozann Whitaker, 1987). The primary goal of the AHP method is to choose an alternative that satisfies the most according to the given set of criteria out of a set of alternatives, or in a simple explanation, to find the weights of criteria in any application to select the best alternative. The AHP calculates the weights of attributes at each level of the hierarchical structure with respect

to its goal. This is done by the expertise decision makers, who have knowledge of the workings of a matrix of pairwise comparison of attributes.

An arrangement of hierarchical structure was made by constructing three different levels, which are upper-level (goal), mid-level (criteria) and sub-level (alternatives). Figure 1 below shows the hierarchical structure.

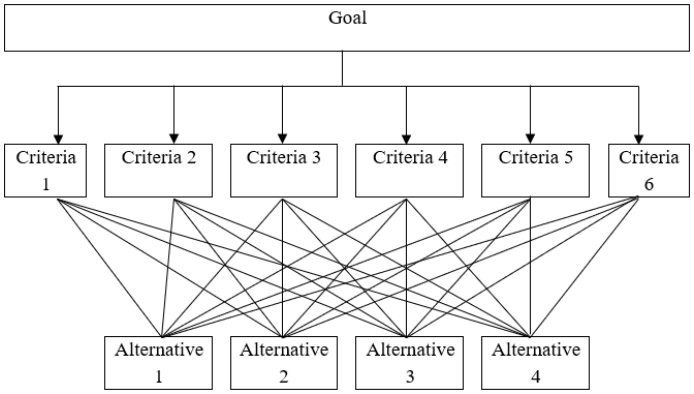

Figure 1. The Hierarchical Structure of AHP

Phase 3 The AHP Algorithm

The AHP algorithm is likely to be mentioned as a calculation part involved in this study. The data obtained from the qualitative method through the questionnaire is used to apply this algorithm. This process will be implemented by using Microsoft Excel 2013.

Step 1: Construct a pairwise comparison matrix

A pairwise comparison can be created by comparing elements in pairs according to the criteria given, which then shapes a matrix. The length of the pairwise matrix is determined based on the number of criteria provided in the decision-making process. A pairwise comparison begins with the upper-level in the hierarchical structure, which is to find the best choice of electronic device for ODL. Next, go to the mid-level, which is the criteria, by taking it to compare to obtain degrees of importance and arranging it in a matrix as shown in Table 1 below.

Table 1. Comparison between Each Criteria made by Saaty.

Criteria Pairing	More Important	Degree of Importance
C_1 and C_2	C_1	C_{12}
C_1 and C_3	C_1	C_{13}
C_1 and C_n	C_1	C_{1n}
C_2 and C_3	C_2	C_{23}
C_2 and C_n	C_2	C_{2n}
C_3 and C_n	C_3	C_{3n}
C_n and C_m	C_n	C_{nm}

Step 2: Perform a pairwise comparison judgement

Table 2. Importance Scale developed by Saaty.

Intensity of Relative Importance	Value	Definition
1	Equal	*n* and *m* are equally important
3	Moderately more important	*n* is moderately more important than *m*

5	Strongly more important	*n* is strongly more important than *m*
7	Very strongly more important	*n* is very strongly more important than *m*
9	Extremely more important	*n* is extremely more important than *m*
2, 4, 6, 8	Intermediate values	Used when a compromise is needed
1/3, 1/5, 1/7, 1/9	Values for inverse comparison	

Once a pairwise comparison is constructed, the pairwise comparison judgement can be performed by evaluating the criteria based on the important scale in Table 3. For example, in the same comparison, if both criteria have equal importance, then it will take the value of 1. Observe that all the diagonals of the pairwise matrix's value are equal to 1. The matrix is represented mathematically as shown (1).

$$\boldsymbol{C} = \begin{bmatrix} \mathbf{1} & \boldsymbol{C_{12}} & \boldsymbol{C_{13}} & \boldsymbol{C_{14}} & \cdots & \boldsymbol{C_{1m}} \\ \frac{\mathbf{1}}{\boldsymbol{C_{12}}} & \mathbf{1} & \boldsymbol{C_{23}} & \boldsymbol{C_{24}} & \cdots & \boldsymbol{C_{2m}} \\ \frac{\mathbf{1}}{\boldsymbol{C_{13}}} & \frac{\mathbf{1}}{\boldsymbol{C_{23}}} & \mathbf{1} & \boldsymbol{C_{34}} & \cdots & \boldsymbol{C_{3m}} \\ \frac{\mathbf{1}}{\boldsymbol{C_{14}}} & \frac{\mathbf{1}}{\boldsymbol{C_{24}}} & \frac{\mathbf{1}}{\boldsymbol{C_{34}}} & \mathbf{1} & \cdots & \boldsymbol{C_{4m}} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\mathbf{1}}{\boldsymbol{C_{1m}}} & \frac{\mathbf{1}}{\boldsymbol{C_{2m}}} & \frac{\mathbf{1}}{\boldsymbol{C_{3m}}} & \frac{\mathbf{1}}{\boldsymbol{C_{4m}}} & \cdots & \mathbf{1} \end{bmatrix} = \boldsymbol{C_{nm}} \quad (1)$$

Where,

$C = C_{nm}, C_{nm} > 0 \; and \; \frac{1}{C_{nm}} = C_{nm}[C_{nm}], where \; n, m = 1,2,3, \ldots$

If $C_{nm} = 1 \; then, n = m$

If $C_{nm} = \frac{1}{C_{mn}} \; then, n \neq m$

C_{nm} shows criteria *n* is more important than *m*. A scale of 1-9 from the most important [9] to equal [1] is used for comparison to define the degree of importance of both criteria. By using formulation in the Table 3, the criterion will be calculated. This is done to change the degree of importance to pairwise comparison.

Table 3. Changing Timetable

	1	2	3	4	5	6	7	8	9	10	11
1	1	2	3	4	5	6	7	8	9	9	9
2		1	2	3	4	5	6	7	8	9	9
3			1	2	3	4	5	6	7	8	9
4				1	2	3	4	5	6	7	8
5					1	2	3	4	5	6	7
6						1	2	3	4	5	6
7							1	2	3	4	5
8								1	2	3	4
9									1	2	3
10										1	2
11											1

Step 3: The synthesis of pairwise comparison

Step I: Calculate C_{nm}

$$\boldsymbol{C_{nm}} = \begin{cases} \boldsymbol{|n-m|+1}, \ \boldsymbol{C_n \, is \, more \, important \, than \, C_m} \\ \boldsymbol{\frac{1}{|n-m|+1}}, \boldsymbol{otherwise} \end{cases} \quad (2)$$

Based on (2), $|n-m|+1$ will be used when the value of $C_n \, is \, more \, important \, than \, C_m$. While $\frac{1}{|n-m|+1}$, will be used if the value of $C_n \, is \, less \, important \, than \, C_m$. To determine the weightage of criteria and the local weight of the alternatives from the constructed pairwise comparison matrix, each value in column, *m* will be divided by the total of the values in column, *m*. This is done through a normalization procedure. Therefore, the normalized matrix will be obtained. All the calculations for every element of the normalized matrix are shown in the next step.

Step II: Calculation of sum of each value according to column

$$\boldsymbol{C_m} = \boldsymbol{\sum_{m=1}^{n} C_{mn}} \quad (3)$$

Where *n* = 1,2,3, …

Note that; $C_{nm} = \frac{1}{C_{mn}} \; or \; C_{mn} = \frac{1}{C_{nm}}$

For example,

$C_1 = C_{11} + C_{21} + C_{31} + \cdots + C_{1n}$

$C_2 = C_{12} + C_{22} + C_{32} + \cdots + C_{2n}$

$C_3 = C_{13} + C_{23} + C_{33} + \cdots + C_{3n}$

$C_n = C_{1n} + C_{2n} + C_{3n} + \cdots + C_{mn}$

Step III: Calculation of normalized pairwise matrix

$$\boldsymbol{V_{nm}} = \boldsymbol{\frac{C_{nm}}{C_m}} \quad (4)$$

Where *n* and *m* = 1, 2, 3, …

The normalized pairwise matrix is represented as follow:

$$\boldsymbol{V} = \begin{bmatrix} \boldsymbol{V_{11}} & \boldsymbol{V_{12}} & \boldsymbol{V_{13}} & \boldsymbol{V_{14}} & \cdots & \boldsymbol{V_{1m}} \\ \boldsymbol{V_{21}} & \boldsymbol{V_{22}} & \boldsymbol{V_{23}} & \boldsymbol{V_{24}} & \cdots & \boldsymbol{V_{2m}} \\ \boldsymbol{V_{31}} & \boldsymbol{V_{32}} & \boldsymbol{V_{33}} & \boldsymbol{V_{34}} & \cdots & \boldsymbol{V_{3m}} \\ \boldsymbol{V_{41}} & \boldsymbol{V_{42}} & \boldsymbol{V_{43}} & \boldsymbol{V_{44}} & \cdots & \boldsymbol{V_{4m}} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{V_{n1}} & \boldsymbol{V_{n2}} & \boldsymbol{V_{n3}} & \boldsymbol{V_{n4}} & \cdots & \boldsymbol{V_{nm}} \end{bmatrix} = \boldsymbol{V_{nm}} \quad (5)$$

Step IV: Calculation of the weight of criteria

Calculate all the elements in the *n* (row by row) by adding the value, then divide the value by the number of criteria in the decision-making process. This is done to find the weightage of each criterion, as shown below.

$$\boldsymbol{W_n} = \boldsymbol{\frac{1}{p}\sum_{m=1}^{n} V_{nm}} \quad (6)$$

Where *n* =1,2,3, … and *p* represents the number of criteria.

The weightage of each criterion can be visualized as below. Note that, the highest weightage is the most important criteria.

$$\boldsymbol{W = [W_1 \quad W_2 \quad W_3 \quad W_4 \quad \cdots \quad W_n]} \tag{7}$$

Step 4: Check the consistency

Although the AHP is considered a consistent and systematic method, the result must depend on the consistency of the pairwise comparison matrix between criteria. The AHP provides a process that contains several steps that need to be followed to measure and check the consistency. Therefore, a pairwise comparison matrix of the criteria or alternatives is compatible if and only if the condition below is satisfied.

$$\boldsymbol{CW^T = nW^T} \tag{8}$$

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & \cdots & C_{1m} \\ C_{21} & C_{22} & C_{23} & C_{24} & \cdots & C_{2m} \\ C_{31} & C_{32} & C_{33} & C_{34} & \cdots & C_{3m} \\ C_{41} & C_{42} & C_{43} & C_{44} & \cdots & C_{4m} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ C_{n1} & C_{n2} & C_{n3} & C_{n4} & \cdots & C_{nm} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ \vdots \\ W_n \end{bmatrix} = n \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ \vdots \\ W_n \end{bmatrix} \tag{9}$$

Step I: Calculate the maximum eigenvalue, e_{max}

$$\boldsymbol{e_{max} = \frac{1}{p}\sum_{n=1}^{r} \frac{n\,CW^T}{nW_n^T}} \tag{10}$$

By performing the calculation of formula above, then e_{max}will be obtained. For example,

$$\boldsymbol{e_{max} = \frac{1}{p}\left[\frac{C_{11}W_1+C_{12}W_2+\cdots+C_{1m}W_1}{W_1} + \frac{C_{21}W_1+C_{22}W_2+\cdots+C_{2m}W_2}{W_2} + \frac{C_{n1}W_1+C_{n2}W_2+\cdots+C_{nm}W_m}{W_m}\right]} \tag{11}$$

Step II: Find the consistency index, CI

The approximation to the consistency index, *CI* can be computed according to the following formula.

$$\boldsymbol{CI = \frac{e_{max} - n}{n-1}} \tag{12}$$

Step III: Determine the random index, RI

Table 4 shows the value random index developed by Saaty in 2008 to determine the random index, *RI*.

Table 4. Random Index (*RI*) Value.

No. of Criteria	*RI*	No. of Criteria	*RI*	No. of Criteria	*RI*	No. of Criteria	*RI*
1	0.00	4	0.90	7	1.32	10	1.49
2	0.00	5	1.12	8	1.41	11	1.51
3	0.58	6	1.24	9	1.45	12	1.48

For example, if the number of criteria, *p* is 4, then the random index value of criteria comparison will be 0.90.

Step IV: Calculate the consistency ratio, CR

At last stage, to obtain *CR*, *CI* will be divided by *RI* as shown below.

$$\boldsymbol{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \tag{13}$$

Note that if the value of *CR* is less than 10% or 0.10, then it can be concluded that the comparisons performed are consistent. However, if the value of *CR* is greater than 10% or 0.10, then there might be an error in the calculation, or the comparisons performed by the decision maker are inconsistent. In this way, the evaluation of the pairwise comparison of criteria needs to be changed or repeated until *CR* is less than 10% or 0.10 is obtained.

Phase 4 Calculation of the weightage of alternative

Throughout the method to find the weightage of criteria, to determine the weightage of each alternative will also be used the same method as before. The weightage of alternative criteria for each criterion can be obtained as shown.

Criteria 1: $W_{A_nC_1} = [W_{A_1C_1}, W_{A_2C_1}, W_{A_3C_1}, W_{A_4C_1}, \dots, W_{A_nC_1}]$

Criteria 2: $W_{A_nC_2} = [W_{A_1C_2}, W_{A_2C_2}, W_{A_3C_2}, W_{A_4C_2}, \dots, W_{A_nC_2}]$

Criteria p: $W_{A_nC_n} = [W_{A_1C_n}, W_{A_2C_n}, W_{A_3C_n}, W_{A_4C_n}, \dots, W_{A_nC_n}]$

$$\boldsymbol{W_A} = \begin{bmatrix} \boldsymbol{W_{A_1C_1}} & \boldsymbol{W_{A_1C_2}} & \boldsymbol{W_{A_1C_3}} & \boldsymbol{W_{A_1C_4}} & \cdots & \boldsymbol{W_{A_1C_n}} \\ \boldsymbol{W_{A_2C_1}} & \boldsymbol{W_{A_2C_2}} & \boldsymbol{W_{A_2C_3}} & \boldsymbol{W_{A_2C_4}} & \cdots & \boldsymbol{W_{A_2C_n}} \\ \boldsymbol{W_{A_3C_1}} & \boldsymbol{W_{A_3C_2}} & \boldsymbol{W_{A_3C_3}} & \boldsymbol{W_{A_3C_4}} & \cdots & \boldsymbol{W_{A_3C_n}} \\ \boldsymbol{W_{A_4C_1}} & \boldsymbol{W_{A_4C_2}} & \boldsymbol{W_{A_4C_3}} & \boldsymbol{W_{A_4C_4}} & \cdots & \boldsymbol{W_{A_4C_n}} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{W_{A_nC_1}} & \boldsymbol{W_{A_nC_2}} & \boldsymbol{W_{A_nC_3}} & \boldsymbol{W_{A_nC_4}} & \cdots & \boldsymbol{W_{A_nC_n}} \end{bmatrix} \begin{bmatrix} \boldsymbol{W_{c_1}} \\ \boldsymbol{W_{c_2}} \\ \boldsymbol{W_{c_3}} \\ \boldsymbol{W_{c_4}} \\ \vdots \\ \boldsymbol{W_{c_n}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{W_{A_1}} \\ \boldsymbol{W_{A_2}} \\ \boldsymbol{W_{A_3}} \\ \boldsymbol{W_{A_4}} \\ \vdots \\ \boldsymbol{W_{A_n}} \end{bmatrix} \tag{14}$$

Phase 5 The development of overall priority ranking

The criteria with the highest weightage are those that are the most significant or likely to be the priority criteria.

Phase 6 Select the best alternative

The best alternative will be selected based on the resultant weightage, which is the highest compared to each other.

2.4 A Numerical Example

This example proposes to demonstrate the development of the AHP in order to be able to select the best alternative. All the steps are performed using the data collected through the questionnaire. Only one respondent's data is selected to present the example. The process begins by constructing the hierarchical structure of the study, as shown below.

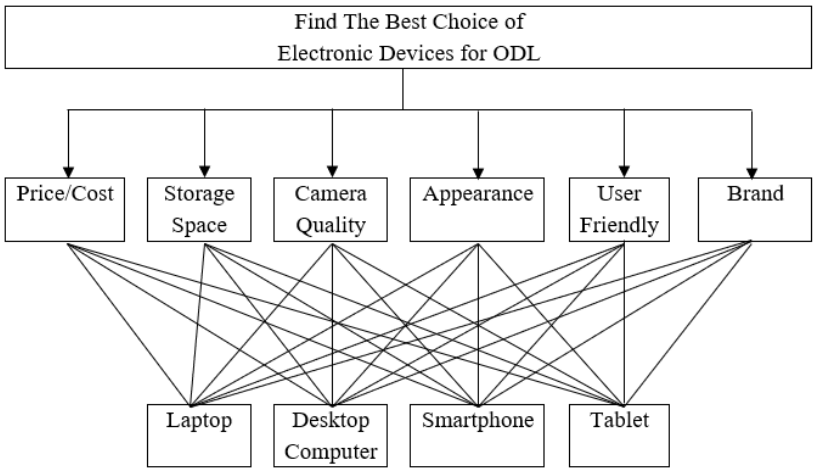

Figure 2. The Hierarchical Structure.

From here, the pairwise comparison has been constructed by referring to the changing schedule in Table 3 as shown Table 5.

Table 5. A Pairwise Comparison, Element Weights, Priority of Criteria.

Criteria	**Price/Cost**	**Storage Space**	**Camera quality**	**Appearance**	**User-friendly**	**Brand**	**Weightage**	**Priority**
Price/ Cost	1	0.3333	4.0000	3.0000	0.3333	2.0000	0.1471	3
Storage Space	3.0000	1	6.0000	5.0000	1.0000	4.0000	0.3271	1
Camera quality	0.2500	0.1667	1	0.5000	0.1667	0.3333	0.0413	6
Appearance	0.3333	0.2000	2.0000	1	0.2000	0.5000	0.0618	5
User-friendly	3.0000	1.0000	6.0000	5.0000	1	4.0000	0.3271	2
Brand	0.5000	0.2500	3.0000	2.0000	0.2500	1	0.0956	4
Total	8.0833	2.9500	22.0000	16.5000	2.9500	11.8330		

CI = 0.0249 *CR* = 0.0201

Next, to calculate the sum of each value according to the column. The calculation was performed as follows:

Criteria 1: Price/Cost

$$C_1 = C_{11} + C_{21} + C_{31} + C_{41} + C_{51} + C_{61}$$
$$= 1 + 3 + 0.25 + 0.3333 + 3 + 0.5$$
$$= 8.0833$$

Criteria 2: Storage Space

$$C_2 = C_{12} + C_{22} + C_{32} + C_{42} + C_{52} + C_{62}$$
$$= 0.3333 + 1 + 0.1667 + 0.2 + 1 + 0.25$$
$$= 2.95$$

Criteria 3: Camera quality

$$C_3 = C_{13} + C_{23} + C_{33} + C_{43} + C_{53} + C_{63}$$
$$= 4 + 6 + 1 + 2 + 6 + 3$$
$$= 22$$

Criteria 4: Appearance

$$C_4 = C_{14} + C_{24} + C_{34} + C_{44} + C_{54} + C_{64}$$
$$= 3 + 5 + 0.5 + 1 + 5 + 2$$
$$= 16.5$$

Criteria 5: User-friendly

$$C_5 = C_{15} + C_{25} + C_{35} + C_{45} + C_{55} + C_{65}$$
$$= 0.3333 + 1 + 0.1667 + 0.2 + 1 + 0.25$$
$$= 2.95$$

Criteria 6: Brand

$$C_6 = C_{16} + C_{26} + C_{36} + C_{46} + C_{56} + C_{66}$$
$$= 2 + 4 + 0.3333 + 0.5 + 4 + 1$$
$$= 11.833$$

Then, the normalized pairwise matrix is determined by dividing each of element in a column with the value of sum of each column. All the data is stored in Table 6.

Table 6. Normalized Pairwise Comparison.

$V_{11} = \frac{1}{8.0833} = 0.1237$	$V_{12} = \frac{0.3333}{2.95} = 0.113$	$V_{13} = \frac{4}{22} = 0.182$	$V_{14} = \frac{3}{16.5} = 0.182$	$V_{15} = \frac{0.3333}{2.95} = 0.113$	$V_{16} = \frac{2}{11.833} = 0.169$
$V_{21} = \frac{3}{8.0833} = 0.3711$	$V_{22} = \frac{1}{2.95} = 0.339$	$V_{23} = \frac{6}{22} = 0.273$	$V_{24} = \frac{5}{16.5} = 0.303$	$V_{25} = \frac{1}{2.95} = 0.339$	$V_{26} = \frac{4}{11.833} = 0.338$
$V_{31} = \frac{0.25}{8.0833} = 0.0309$	$V_{32} = \frac{0.1667}{2.95} = 0.0565$	$V_{33} = \frac{1}{22} = 0.045$	$V_{34} = \frac{0.5}{16.5} = 0.03$	$V_{35} = \frac{0.1667}{2.95} = 0.0565$	$V_{36} = \frac{0.3333}{11.833} = 0.0282$
$V_{41} = \frac{0.3333}{8.0833} = 0.0412$	$V_{42} = \frac{0.2}{2.95} = 0.0678$	$V_{43} = \frac{2}{22} = 0.091$	$V_{44} = \frac{1}{16.5} = 0.061$	$V_{45} = \frac{0.2}{2.95} = 0.0678$	$V_{46} = \frac{0.5}{11.833} = 0.0423$
$V_{51} = \frac{3}{8.0833} = 0.3711$	$V_{52} = \frac{1}{2.95} = 0.339$	$V_{53} = \frac{6}{22} = 0.273$	$V_{54} = \frac{5}{16.5} = 0.303$	$V_{55} = \frac{1}{2.95} = 0.339$	$V_{56} = \frac{4}{11.833} = 0.338$
$V_{61} = \frac{0.5}{8.0833} = 0.0619$	$V_{62} = \frac{0.25}{2.95} = 0.0847$	$V_{63} = \frac{3}{22} = 0.136$	$V_{64} = \frac{2}{16.5} = 0.121$	$V_{65} = \frac{0.25}{2.95} = 0.0847$	$V_{66} = \frac{1}{11.833} = 0.0845$

$$V = \begin{bmatrix} 0.1237 & 0.113 & 0.182 & 0.182 & 0.113 & 0.169 \\ 0.3711 & 0.339 & 0.273 & 0.303 & 0.339 & 0.338 \\ 0.0309 & 0.0565 & 0.045 & 0.03 & 0.0565 & 0.0282 \\ 0.0412 & 0.0678 & 0.091 & 0.061 & 0.0678 & 0.0423 \\ 0.3711 & 0.339 & 0.273 & 0.303 & 0.3339 & 0.338 \\ 0.0619 & 0.0847 & 0.136 & 0.121 & 0.0847 & 0.0845 \end{bmatrix}$$

This is continued by finding the weightage of each criterion. This is done by adding the value of each row in the normalized pairwise comparison and dividing it by the number of criteria of study in decision-making. Table 7 shows the data for the weightage of criteria that have been calculated and recorded.

Table 7. Weightage of Criteria.

$\mathbf{W_1}$	$\mathbf{W_2}$	$\mathbf{W_3}$	$\mathbf{W_4}$	$\mathbf{W_5}$	$\mathbf{W_6}$
$W_1 = \frac{0.8827}{6}$ $= 0.1471$	$W_2 = \frac{1.9631}{6}$ $= 0.3271$	$W_3 = \frac{0.2471}{6}$ $= 0.0413$	$W_4 = \frac{0.3711}{6}$ $= 0.0618$	$W_5 = \frac{1.9631}{6}$ $= 0.3271$	$W_6 = \frac{0.5728}{6}$ $= 0.0956$

Lastly, the consistency is checked by multiplying the pairwise comparison matrix with the weightage of the criteria to satisfy (8). The calculation is performed below.

$$\begin{bmatrix} 1 & 0.3333 & 4 & 3 & 0.3333 & 2 \\ 3 & 1 & 6 & 5 & 1 & 4 \\ 0.25 & 0.1667 & 1 & 0.5 & 0.1667 & 0.3333 \\ 0.3333 & 0.2 & 2 & 1 & 0.2 & 0.5 \\ 3 & 1 & 6 & 5 & 1 & 4 \\ 0.5 & 0.25 & 3 & 2 & 0.25 & 1 \end{bmatrix} \begin{bmatrix} 0.1471 \\ 0.3271 \\ 0.0413 \\ 0.0618 \\ 0.3271 \\ 0.0956 \end{bmatrix} = 6 \begin{bmatrix} 0.9068 \\ 2.0344 \\ 0.2499 \\ 0.3720 \\ 2.0344 \\ 0.5801 \end{bmatrix}$$

Second, the maximum eigenvalue is determined to find the consistency index later.

$$\begin{aligned} e_{max} &= \frac{1}{6}\sum \frac{0.9068}{0.1471} + \frac{2.0344}{0.3271} + \frac{0.2499}{0.0413} + \frac{0.3720}{0.0618} + \frac{2.0344}{0.3271} + \frac{0.5801}{0.0956} \\ &= \frac{1}{6}\sum 6.1645 + 6.2195 + 6.0508 + 6.0194 + 6.2195 + 6.0680 \\ &= 6.1244 \end{aligned}$$

Third, the consistency index, *CI* is calculated by using the formula stated in (12).

$$CI = \frac{6.1244 - 6}{6 - 1} = 0.0249$$

Fourth, the *RI* is determined by referring to the random index value in Table 4. There are six criteria provided in the decision-making process. This can conclude that the *RI* value is equal to 1.24.

Lastly, to complete the check consistency process, consistency ratio, *CR*, is calculated by dividing *CI* by *RI* as follows.

$$CR = \frac{0.0249}{1.2358} = 0.0201$$

Based on the value of *CR*, we can conclude that the pairwise comparisons performed are effective and consistent because the value is 0.0201, which is less than 10% or 0.1000.

After the weightage of criteria is successfully obtained, the development of AHP resumed with finding the weightage of alternatives. There are four alternatives preferred in the study, which are: laptop, desktop computer, smartphone, and tablet. The same method will be applied to find the weightage of alternatives. However, the weightage of each alternative in relation to each criterion must be determined first. Throughout the process of calculation, the results are as follows:

Table 8. Pairwise Comparison Respect to Price/Cost.

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.25	0.25	0.25	0.25	0.25
Desktop computer	0.25	0.25	0.25	0.25	0.25
Smartphone	0.25	0.25	0.25	0.25	0.25
Tablet	0.25	0.25	0.25	0.25	0.25

$$W_{A_nC_1} = [W_{A_1C_1}, W_{A_2C_1}, W_{A_3C_1}, W_{A_4C_1}] = [0.25, 0.25, 0.25, 0.25]$$

Table 9. Pairwise Comparison Respect to Storage Space.

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.25	0.25	0.25	0.25	0.25
Desktop computer	0.25	0.25	0.25	0.25	0.25
Smartphone	0.25	0.25	0.25	0.25	0.25
Tablet	0.25	0.25	0.25	0.25	0.25

$$W_{A_nC_2} = [W_{A_1C_2}, W_{A_2C_2}, W_{A_3C_2}, W_{A_4C_2}] = [0.25, 0.25, 0.25, 0.25]$$

Table 10. Pairwise Comparison Respect to Camera Quality.

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.142857	0.142857	0.142857	0.142857	0.142857
Desktop computer	0.142857	0.142857	0.142857	0.142857	0.142857
Smartphone	0.571429	0.571429	0.571429	0.571429	0.571429
Tablet	0.142857	0.142857	0.142857	0.142857	0.142857

$$W_{A_nC_3} = [W_{A_1C_3}, W_{A_2C_3}, W_{A_3C_3}, W_{A_4C_3}] = [0.142857, 0.142857, 0.571429, 0.142857]$$

Table 11. Pairwise Comparison Respect to Appearance.

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.20	0.20	0.20	0.20	0.20
Desktop computer	0.20	0.20	0.20	0.20	0.20
Smartphone	0.40	0.40	0.40	0.40	0.40
Tablet	0.20	0.20	0.20	0.20	0.20

$$W_{A_nC_4} = [W_{A_1C_4}, W_{A_2C_4}, W_{A_3C_4}, W_{A_4C_4}] = [0.20, 0.20, 0.40, 0.20]$$

Table 12. Pairwise Comparison Respect to User Friendly.

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.25	0.25	0.25	0.25	0.25
Desktop computer	0.25	0.25	0.25	0.25	0.25
Smartphone	0.25	0.25	0.25	0.25	0.25
Tablet	0.25	0.25	0.25	0.25	0.25

$$W_{A_nC_5} = [W_{A_1C_5}, W_{A_2C_5}, W_{A_3C_5}, W_{A_4C_5}] = [0.25, 0.25, 0.25, 0.25]$$

Table 13. Pairwise Comparison Respect to Brand

Alternatives	Laptop	Desktop computer	Smartphone	Tablet	Weightage
Laptop	0.20	0.20	0.20	0.20	0.20
Desktop computer	0.20	0.20	0.20	0.20	0.20
Smartphone	0.40	0.40	0.40	0.40	0.40
Tablet	0.20	0.20	0.20	0.20	0.20

$$W_{A_nC_6} = [W_{A_1C_6}, W_{A_2C_6}, W_{A_3C_6}, W_{A_4C_6}] = [0.20, 0.20, 0.40, 0.20]$$

$$W_A = \begin{bmatrix} W_{A_1C_1} & W_{A_1C_2} & W_{A_1C_3} & W_{A_1C_4} & W_{A_1C_5} & W_{A_1C_6} \\ W_{A_2C_1} & W_{A_2C_2} & W_{A_2C_3} & W_{A_2C_4} & W_{A_2C_5} & W_{A_2C_6} \\ W_{A_3C_1} & W_{A_3C_2} & W_{A_3C_3} & W_{A_3C_4} & W_{A_3C_5} & W_{A_3C_6} \\ W_{A_4C_1} & W_{A_4C_2} & W_{A_4C_3} & W_{A_4C_4} & W_{A_4C_5} & W_{A_4C_6} \end{bmatrix} \begin{bmatrix} W_{C_1} \\ W_{C_2} \\ W_{C_3} \\ W_{C_4} \\ W_{C_5} \\ W_{C_6} \end{bmatrix} = \begin{bmatrix} W_{A_1} \\ W_{A_2} \\ W_{A_3} \\ W_{A_4} \end{bmatrix}$$

$$= \begin{bmatrix} 0.25 & 0.25 & 0.142857 & 0.20 & 0.25 & 0.20 \\ 0.25 & 0.25 & 0.142857 & 0.20 & 0.25 & 0.20 \\ 0.25 & 0.25 & 0.571429 & 0.40 & 0.25 & 0.40 \\ 0.25 & 0.25 & 0.142857 & 0.20 & 0.25 & 0.20 \end{bmatrix} \begin{bmatrix} 0.1471 \\ 0.3271 \\ 0.0413 \\ 0.0618 \\ 0.3271 \\ 0.0956 \end{bmatrix} = \begin{bmatrix} 0.237707 \\ 0.237707 \\ 0.286878 \\ 0.237707 \end{bmatrix}$$

Table 14. The Priority of Alternatives.

Weightage of alternatives	Priority
0.237707	2
0.237707	3
0.286878	1
0.237707	4

Based on the result, the smartphone has the priority over others. However, the result is contrary to the respondent's choice of the most preferable type to use based on the data collected, which is a laptop. It can be concluded that the respondent preferred to use a smartphone during ODL after emphasising all the factors involved in choosing the most preferable type of electronic device.

3. Result and Discussion

Based on the data collected through the questionnaire, several analyses have been conducted, and the results are discussed thoroughly in this section.

3.1 Demographic Analysis

Consecutively collecting the data, the study has been conducted in several areas, which are the field of education, level of education, and age. Therefore, it assists in getting the desired data successfully. Table 15 shows the result of a demographic analysis of all the respondents that participated in the survey.

Table 15. Demographic Analysis.

Demographic	Information	Frequency	Percentage (%)
Field of Education	Business & Management	33	66
	Science & Technology	11	22
	Social Sciences & Humanities	6	12
Level of Education	Diploma	36	72
	Bachelor/Degree	14	28
	Master	0	0
	PHD	0	0
Age	18 – 20 years old	36	72
	21 years old and above	14	28

3.2 Most Preferable Electronic Device for ODL Analysis

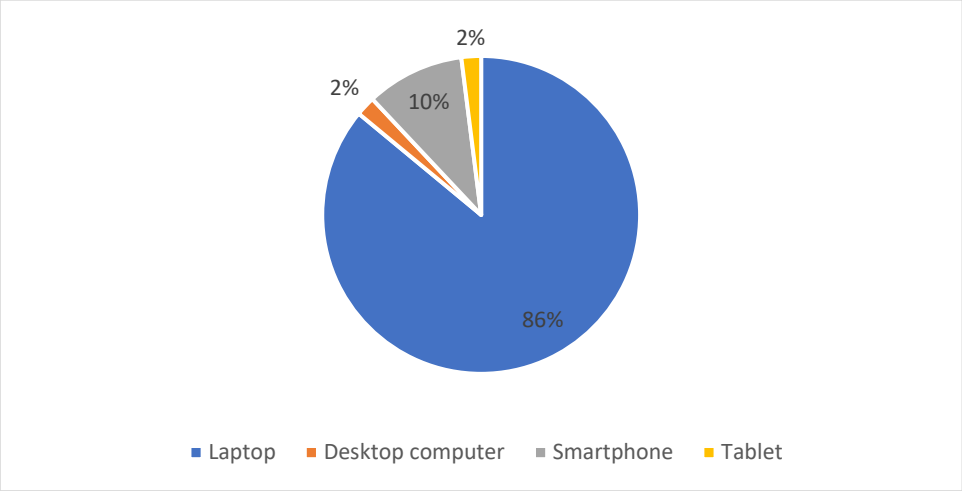

Figure 3. Pie Chart of Most Preferable Electronic Device for ODL.

Figure 3 above shows a presentation of a pie chart of the most preferable type of electronic device for ODL. This shows that the laptop was voted as the most preferred electronic device, with 86% of respondents choosing to use it for ODL. Following, the second highest is smartphones, with 10% of respondents. Lastly, both desktop computers and tablets have the lowest value, with only 2% of each preferring to use them for ODL. It can be concluded that the laptop received the highest vote, maybe due to its convenience in completing the tasks given by the lecturer. A poll was conducted and over 1200 college students from around United States were surveyed. The result came out by 88% of college students said they own a laptop and 85% percent said they own a smartphone (Michael Hart, 2015).

3.3 Criteria Weightage Analysis by Rank

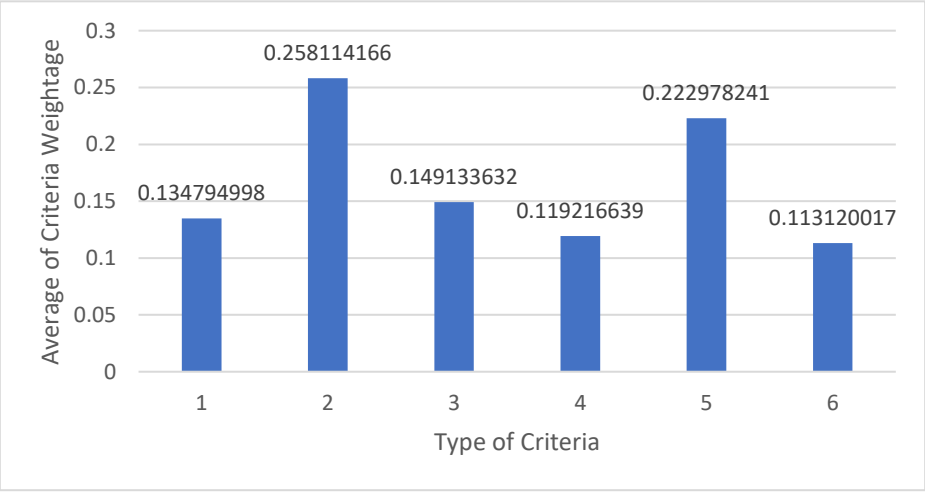

Figure 4. Bar Graph of Criteria Rank.

Figure 4 above shows a bar graph of the rank of criteria. There are six criteria provided in this study for determining the best choice of electronic device for ODL. The following criteria are price/cost, storage space, camera quality, appearance, user-friendly, and brand and are labelled as 1, 2, 3, 4, 5, and 6 respectively in the

graph. The data collected from 50 respondents through the questionnaire was used to find the weightage of the criteria. All criteria were evaluated by using a scale from 1 to 9, where 1 represents the most important and 9 represents the least important. The average of each criterion's weightage was later determined. Then, the criteria were ranked based on the average of each criterion's weightage.

Concisely, the priority of criteria to be focused on for choosing the best electronic device compared to all other criteria is criteria 2, which is storage space, with an average criteria weightage of 0.258114166. Then, the second rank, with a weight of 0.222978241, goes to criteria 5, which is user-friendly. Criteria 3, camera quality, comes in third place with a weight of 0.149133632. The fourth position, with a weight of 0.134794998, is price/cost. The fifth position, with a weight of 0.119216639, is appearance. Finally, the last rank, with a weight of 0.113120017, is criteria 6, brand.

Referring to the average criteria weightage, it can be assumed that the respondents prefer to choose the best electronic device for ODL by focusing more on storage space. As the respondents consist of students, they need sufficient storage space to do their work and store important notes given by their lecturer. Moreover, this also shows that the brand of an electronic device is the least important factor to students in deciding the best electronic device. The study's goal of determining the factors that influence UiTM students' choice of preferred type of electronic device is met.

3.4 Alternative Weightage Analysis by Rank

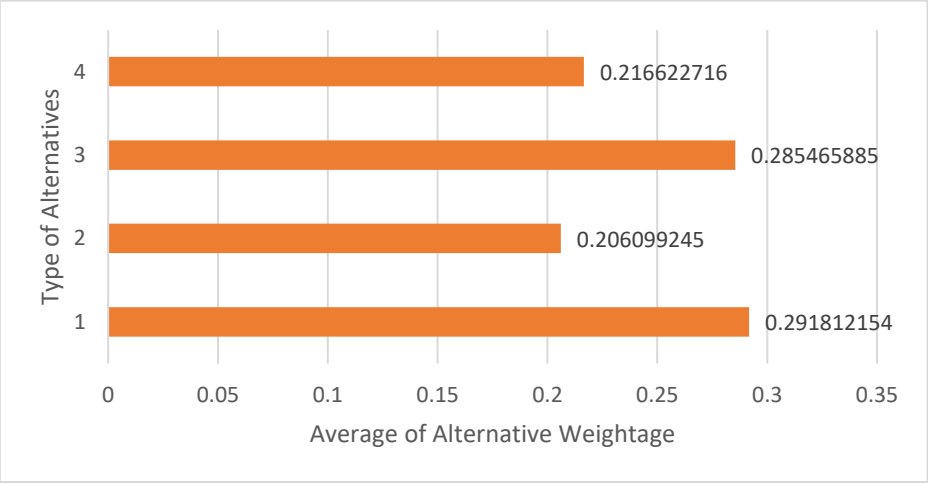

Figure 5. Bar Graph of Alternatives Rank.

Figure 5 above represents a bar graph of the rank of alternatives. There are four alternatives proposed in this study. The alternatives are laptops, desktop computers, smartphones, and tablets, and they are labelled 1, 2, 3, and 4 respectively. All alternatives have been evaluated using a scale from 1 (most important) to 9 (least important). The average of each alternative's weightage is calculated to determine the rank of alternatives.

Briefly, the highest rank of alternatives that are the most preferred by respondents is the laptop compared to others, with a value of 0.291812154. Next, the second rank, with a weight of 0.285465885, is the smartphone. The tablet is ranked third, with a weight of 0.216622716. Lastly, the lowest rank is the desktop computer, with a weight of 0.206099245.

According to the average alternative weightage, it can be concluded that the majority of the respondents chose laptops as the most preferable electronic device for ODL. Its characteristics support all the criteria provided in the study. Furthermore, the bar graph also indicates that the least preferable electronic device is the desktop computer. This might be due to the troublesome task of bringing the computer everywhere. The objective of the study to find the best choice of electronic device for ODL using the AHP is achieved successfully. Hence, it can be affirmed that the best alternative for ODL is choosing a laptop.

4. Conclusion and Recommendations

This section overall discusses that the objectives of study are achieved successfully, the advantages and disadvantages of the AHP in the decision-making process and recommends several improvements to the AHP method.

4.1 Conclusion

According to the results obtained throughout the study, it is proved that all the objectives of the study are fulfilled. Figure 3 shows the first objective is achieved by expressing that the most preferable type of electronic device among UiTM students for ODL is a laptop. Then, Figure 4 signifies the second objective is also reached by revealing the main factor that leads the UiTM students to choose the preferable type of electronic device: storage space. Lastly, based on Figure 5, it is found that a laptop is the best choice of electronic device for ODL among UiTM students. This directly shows that the last objective has also been accomplished.

A numerical example is presented to demonstrate the performance of the methodology. The use of the AHP method is proved to assist UiTM students to analyse and select the best alternative with respect to the criteria provided. The AHP method is one of the most suitable methodologies to use for the decision-making process. There are many advantages to using AHP in a decision-making study.

One of the advantages of the AHP is that it provides a simple and flexible model for solving a complex problem. The nature of the decision process has made it applicable to assist the decision maker in making any judgement precisely by considering the qualitative and quantitative information throughout the decision process. It also allows experts and decision-makers from different backgrounds to judge their studies. In simple words, the AHP can be widely used in many aspects such as factor, benefit, risk analysis, and many more that are related to deciding a decision among alternatives with respect to the criteria. The advancement of technology nowadays has made the AHP method easier to apply as it is fast and accurate.

Even though the AHP has many advantages, it still has many disadvantages during its development. Briefly, the AHP method cannot assure the decision made as definitely. This is because AHP has a subjective nature to the modelling process. This means it depends on the evaluation of decision makers based on their preference or interest. For that reason, using semantic variables makes the evaluation process more realistic because a simple evaluation is not an accurate process and has fuzziness in its work. The AHP method is famously known as the easiest method to solve complex problems in the decision-making process. However, it has a limitation. Although the AHP is one of the most advanced methods available in the field of management science and operations research, the complexity involved in using this tool makes it difficult to apply (Prachi Juneja, 2015). For example, when the number of criteria in a hierarchical structure increase, the number of pair comparisons also increases. Therefore, building the AHP model will take more time and effort.

4.2 Recommendations

In the presence of methodology processes, along with through literature survey by the authors, the AHP is strongly recommend to future researchers as the most suitable MCDM method when analysing complex decision-making problems (Ansah et al, 2015). It is recommended to have an expert decision maker evaluate measurable data so that the target decision-maker is willing to fully commit and devote time to the evaluation process. Therefore, the data collected can be affirmed to be more accurate and feasible. For future studies, combining the AHP method with other decision-making methods can help to ensure a more integrated study.

Acknowledgements

The authors express their heartfelt gratitude to the editors and referees for their helpful suggestions and constructive comments.

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