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AN ANALYTIC HIERARCHY PROCESS (AHP) APPROACH FOR THE SELECTION OF GADGETS IN EDUCATION

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ABSTRACT

In the COVID-19 pandemic, the selection of gadgets plays an essential role in academics because the majority of the classes are held online. It is important to ensure that the virtual learning session runs smoothly, just as a real one does. The criteria that have been selected can have an impact on the learning process, making the device selection process important. Moreover, the selection of devices is also essential to ensuring that the devices used can assist in the learning process. This study aims to analyse the most preferable gadget by using the Analytic Hierarchy Process (AHP). This study is conducted at UiTM Seremban 3 and focuses on a 250-person sample size, which consists of lecturers and students. In this study, seven criteria, which are brand, price, Random-access Memory (RAM), battery capacity, storage size, screen size and resolution, and weight, and four alternatives, namely, desktop computer, laptop, tablet, and smartphone, are considered. The result of the analysis shows that the most preferable criteria is storage size, and the most preferable alternative is a smartphone.

Keywords: *Analytic Hierarchy Process, COVID-19, Education, Gadget Selection, Learning.*

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1. Introduction

Decision-making involves deciding between different options or choosing an option of action based on a set of standards, preferences, or values. It entails assessing many possibilities, weighing their potential results and consequences, and eventually selecting the optimal decision in considering the information at hand and one's own judgements. Simple, normal judgements can be made as well as sophisticated, high-stakes decisions that demand careful analysis and evaluation of numerous factors. Effective decision-making is an essential skill in both personal and professional situations because it helps people and organizations to achieve their objectives and take advantage of opportunities and difficulties. Owing to the fact that every organization’s ability to survive hinges on the way its leaders make decisions that have an influence on everyone inside the organization (Obioma Ejimabo, 2015).

Multiple Criteria Decision Making (MCDM), a subfield of decision science, focuses with making choices when there are several criteria or objectives to take into consideration. Different choices are ranked and evaluated using MCDM techniques based on a variety of criteria, some of which may have competing objectives or involve trade-offs. The systematic method of decision-making offered by MCDM approaches takes into account every relevant criterion. One of the most popular MCDM approaches, the Analytic Hierarchy Process (AHP) method is a broadly applied multi-criteria decision-making method to determine the weights of criteria and priorities of alternatives in a structured manner based on pairwise comparison (Liu et al., 2020). It is used to determine ratio scales from paired comparisons that are continuous or discrete (Saaty, 1987). AHP is a multicriteria decision-making approach that assists decision-makers in choosing among options. AHP can be used by decision-makers who need to make a choice in unclear situations. Moreover, the AHP is a systematic approach for assisting people in dealing with difficult decisions. It offers a thorough and coherent framework for organising a problem, describing and measuring its parts, linking those elements to objectives, and assessing different courses of action (Liu et al., 2020)

Businesses, institutions, and colleges in Malaysia have been forced to close because of the COVID-19 outbreak. To ensure that students can continue with their studies, organisations have chosen to offer online distance learning for educators and students. The workload has doubled, though, and educators require the right tools to make sure the teaching and learning process goes smoothly. Examples of gadgets in this study include smartphones, tablets, laptops, and desktop computers. These kinds of tools are necessary for educators to succeed in virtual classrooms. Therefore, the element of gadget selection is crucial. Poor device selection might result in negative consequences, including subpar software, out-of-date versions, and ineffective work. The purpose of this study is to determine the most preferred gadget and the criteria for choosing a device using AHP.

2. AHP Comparison Matrix

The comparison matrix ($n \times n$) for criteria and alternatives with respect to each criterion should be derived in the AHP approach. The comparison matrix is in the following form:

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

The diagonal entries from a_{11} to a_{nn} take the value 1 ($[a_{ii} \dots a_{nn}] = 1$). The rest entries take the value between 1–9 describing numerical values of comparison matrix (Enrique Mu, 2018). If a_{12} takes the value 3, then a_{21} becomes $1/a_{12}$ that is 1/3 ($[a_{ji} = 1/a_{ij}]$). There are some steps to be followed to reach results using AHP method (Enrique Mu, 2018). The principle of working with AHP method is stepwise explained below.

Step 1. Development the model: The issue and the objective of decision-making are introduced hierarchically into the context of relevant choice elements at the first step (Taherdoost, 2018). The selection problem is divided into three levels, with goals, criteria, and alternatives making up the first, second, and third levels of the hierarchy, respectively shown in Figure 1.

Step 2. Calculation of the weightage for criteria: Pairwise comparisons between criteria are carried out as a result. After that, judgements are evaluated for consistency to ensure that they are transitive and proportionate.

By taking into consideration a scale created by Saaty, the pairwise comparisons between the criteria should be performed to obtain the weightage (Enrique Mu, 2018). Table 1 below shows the scale of pairwise comparisons.

Table 1: Scale of pairwise comparisons by Saaty

Intensity of Importance	Definition	Explanation
1	Equally	Two factors contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favour one factor to another
5	Strongly	Experience and judgment strongly or essentially favour one factor over another
7	Very strongly	A factor is strongly favoured over another and its dominance is showed in practice
9	Extremely	The evidence of favouring one factor over another is of the highest degree possible of an affirmation
2, 4, 6, 8	Intermediate	Used to represent compromises between the preferences in weights 1, 3, 5, 7, and 9
Reciprocals	Opposites	Used for inverse comparison

Based on Table 1, the most important criteria are represented by a maximum numerical value of 9, while the least important criteria are represented by a minimum numerical value of 1. The numbers 2 and 3 indicate slightly more significant criteria, whereas 4 and 5 describe significantly more significant criteria. It is necessary to calculate the normalised matrix after defining the comparison matrix of criteria, which is done in the following order: (1) Add the values in each column of the comparison matrix; (2) Divide each value by the sum of related columns; (3) To obtain the weightage for the criteria, take the average of each row in the normalised matrix.

The comparison matrix's consistency is evaluated as follows: (1) Multiply each value in the first column of the comparison matrix by the first weightage criterion, then multiply each value in the second column by the second weightage criterion, and so on for all columns; (2) Add up the values in each row to get what are known as weightage sums; (3) Divide the weightage sums by the weightage of each criterion that corresponds to them. Take the values' average after division to determine $e_{\max}$. (4) Use the following formulas to determine the consistency index (CI) and consistency ratio (CR) (n is the number of compared elements):

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

$$CR = \frac{CI}{RI} < 0.1 \tag{2}$$

where a comparison matrix created at random gives the values that are available to the Random Index (RI). To prove that CR is consistent, it must be set to 0.1. For $n = 4$, RI has a value of 0.9; for $n = 5$, RI has a value of 1.12; and for $n = 6$, RI has a value of 1.24 (Enrique Mu, 2018).

Step 3. Calculation of the weightage for alternative: The pairwise comparison is done between the alternatives with respect to each criterion. The pairwise comparisons are later evaluated for consistency. (1) The comparison matrix is constructed with each criterion in mind; (2) The normalised matrix is calculated and the average of the rows is taken to determine the priorities for each alternative; and (3) The consistency checks are the same.

Step 4. Calculation for the final weightage: The final weightage is determined by adding the weightage of each criterion to the weightage of the alternatives with respect to each criterion. The best choice is the alternative with the highest final weightage (Enrique Mu, 2018).

The weightage of alternatives for each criterion and priorities of criteria are considered. By multiplying each alternative weightage (with respect to each criterion) by the related criterion weights and then adding the sum of each row, the final weightage of the alternatives is determined. Consequently, the best alternative is obtained.

3. Application of AHP in Gadget Selection

The results of the survey, which were given to 250 educators and students at UiTM Seremban 3, have been compiled. The data is cleaned, and the results are calculated using Microsoft Excel. The AHP has been used to determine the weightage for the criterion and alternatives. To evaluate the data for this study using the AHP approach, the weights of the criterion and the alternative must be determined. As a result, the weightage of criteria and alternatives can be determined, and the option with the highest value will be selected. A few approaches are used to calculate the weightage of criteria and alternatives.

Table 2 summarises the results of the comparison matrix for the criteria. The normalised matrix for Table 2 is shown in Table 3. We use the average of each row from the normalised matrix in Table 3 to determine the weightage for the criteria.

The criteria and alternatives for gadget selection are derived from surveying workers at gadget stores in a mall. Surveying employees at gadget retailers in a mall derived the selection criteria and alternatives. Valuable insights are obtained through interacting with these employees and asking them specific questions about client preferences and trends. The survey results provide a beginning point for this study's gadget selection criteria and alternatives, which are then further investigated and evaluated before making the final decision.

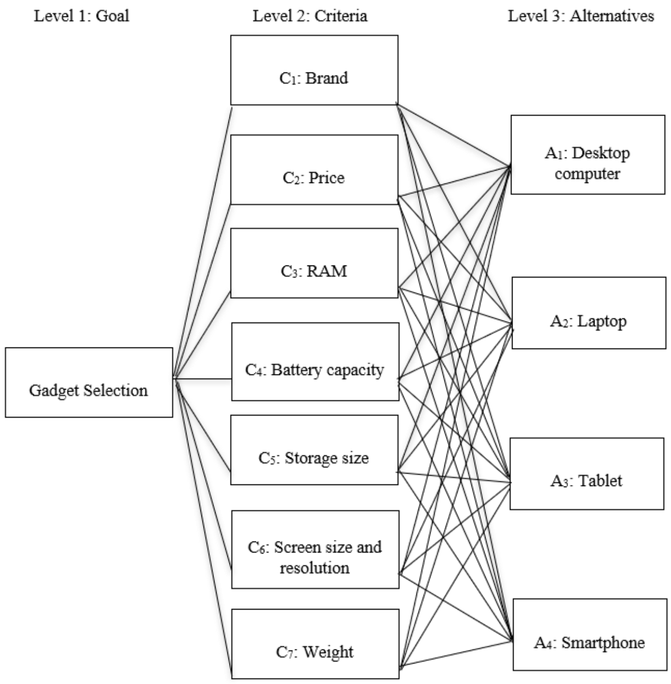

Figure 1. Hierarchy structure for the selection of gadgets

Table 2: Comparison matrix for criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	1	3	1	1	2	1	4
C_2	1/3	1	1/3	1/3	1/2	1/3	2
C_3	1	3	1	1	1	2	1
C_4	1	3	1	1	2	1	4
C_5	1/2	2	1	1/2	1	1/2	3
C_6	1	3	1/2	1	2	1	4
C_7	1/4	1/2	1	1/4	1/3	1/4	1
Sum	5.0833	15.50	5.8333	5.0833	8.8333	6.0833	19

Table 3: Normalized matrix and criteria weightage

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	**Weightage**
C_1	0.1967	0.1934	0.1714	0.1967	0.2264	0.1644	0.2105	0.1942
C_2	0.0656	0.0645	0.0571	0.0656	0.0566	0.0548	0.1053	0.0671
C_3	0.1967	0.1935	0.1714	0.1967	0.1132	0.3288	0.0526	0.1790
C_4	0.1967	0.1935	0.1714	0.1967	0.2264	0.1644	0.2105	0.1942
C_5	0.0984	0.1290	0.1714	0.0984	0.1132	0.0822	0.1579	0.1215
C_6	0.1967	0.1935	0.0857	0.1967	0.2264	0.1644	0.2105	0.1820
C_7	0.0492	0.0323	0.1714	0.0492	0.0377	0.0411	0.0526	0.0619

The consistency of comparison matrix should be checked. The comparison matrix is multiplied with the weightage of criteria, and the weightage sum is calculated as shown in Table 4.

Table 4: Results of weightage sum for criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	**Weightage sum**
Criteria Weightage	0.1942	0.0671	0.1790	0.1942	0.1215	0.1820	0.0619	
C_1	1	3	1	1	2	1	4	1.4414
C_2	1/3	1	1/3	1/3	1/2	1/3	2	0.5015
C_3	1	3	1	1	1	2	1	1.3161
C_4	1	3	1	1	2	1	4	1.4414
C_5	1/2	2	1	1/2	1	1/2	3	0.9057
C_6	1	3	1/2	1	2	1	4	1.3519
C_7	1/4	1/2	1	1/4	1/3	1/4	1	0.4576

The weightage sum for each criterion is divided by respective weightage to find eigenvalues, then average is calculated to find the maximum eigenvalue $e_{\max}$. Table 5 below shows the result for the maximum eigenvalues, $e_{\max}$.

Table 5: Result for maximum eigenvalues, e_{max}

Criteria	**Weightage for Criteria**	**Eigenvalues**
C_1	0.1942	1.4414
C_2	0.0671	0.5015
C_3	0.1790	1.3161
C_4	0.1942	1.4414
C_5	0.1215	0.9057

C_6	0.1820	1.3519
C_7	0.0619	0.4576
Maximum eigenvalue, e_{max}		**7.4157**

By using Equation (1) and (2), the CI and CR are calculated.

$$CI = \frac{7.415676 - 7}{7 - 1} = 0.0693 \qquad CR = \frac{0.069279}{1.32} = 0.0524 < 0.1$$

Hence, the comparison matrix is perfectly consistent.

Figure 2 shows the computer simulation results of the weightage for criteria.

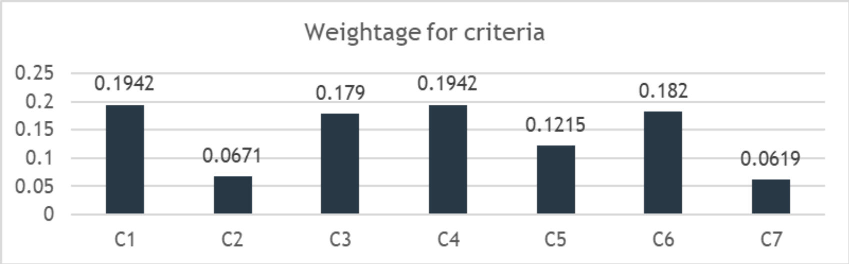

Figure 2. Computer simulation results of the weightage for criteria

The same steps are done for each criterion by considering all alternatives.

For brand alternative, comparison matrix is shown in Table 6, and the computer simulation results of the weightage for brand alternative are shown in Figure 3

(e_{max}: 4.01218063; CI: 0.0041; CR: 0.0045 < 0.1)

Table 6: Pairwise comparisons between brand alternative

	A_1	**A_2**	**A_3**	**A_4**
A_1	1	1/2	2	1/2
A_2	2	1	3	1
A_3	1/2	1/3	1	1/3
A_4	2	1	3	1
Sum	5.5	2.8333	9	2.8333

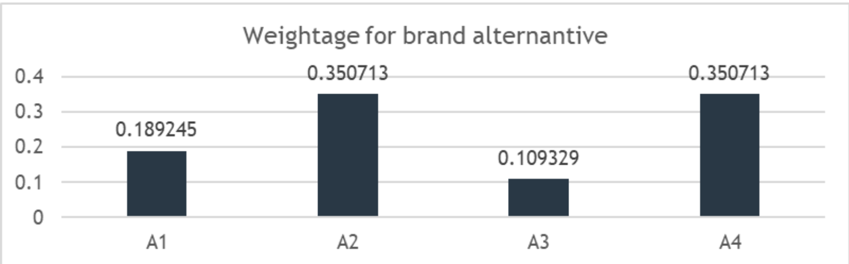

Figure 3. Computer simulation results of the weightage for brand alternative

For price alternative, comparison matrix is shown in Table 7, and the computer simulation results of the weightage for price alternative are shown in Figure 4.

(e_{max}: 4.025094697; CI: 0.0084; CR: 0.0093 < 0.1)

Table 7: Pairwise comparisons between price alternative

	A_1	A_2	A_3	A_4
A_1	1	1	4	2
A_2	1	1	4	2
A_3	1/4	1/4	1	1/3
A_4	1/3	1/2	3	1
Sum	2.75	2.75	12	5.3333

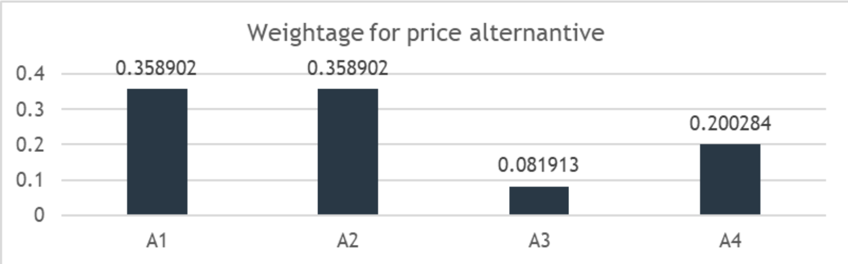

Figure 4. Computer simulation results of the weightage for price alternative

For RAM alternative, comparison matrix is shown in Table 8, and the computer simulation results of the weightage for RAM alternative are shown in Figure 5.

($e_{\max}$: 4; CI: 0; CR: $0 < 0.1$)

Table 8: Pairwise comparisons between RAM alternative

	A_1	A_2	A_3	A_4
A_1	1	1	1	1
A_2	1	1	1	1
A_3	1	1	1	1
A_4	1	1	1	1
Sum	4	4	4	4

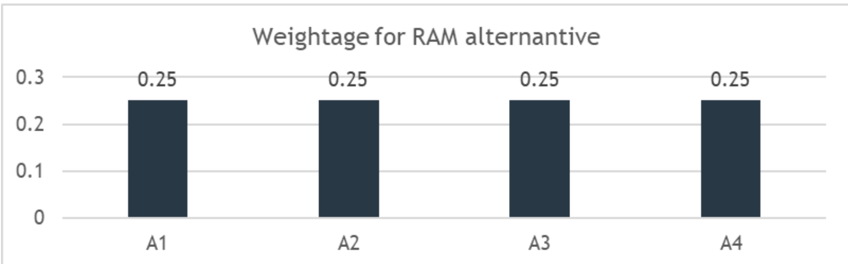

Figure 5. Computer simulation results of the weightage for RAM alternative

For battery capacity alternative, comparison matrix is shown in Table 9, and the computer simulation results of the weightage for battery capacity alternative are shown in Figure 6.

($e_{\max}$: 4; CI: 0; CR: $0 < 0.1$)

Table 9: Pairwise comparisons between battery capacity alternative

	A_1	A_2	A_3	A_4
A_1	1	1	1	1
A_2	1	1	1	1
A_3	1	1	1	1
A_4	1	1	1	1
Sum	4	4	4	4

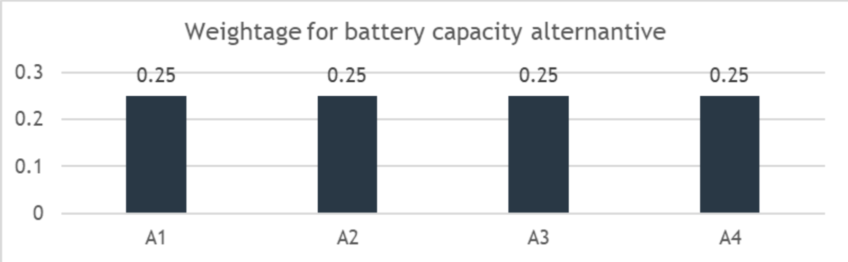

Figure 6. Computer simulation results of the weightage for battery capacity alternative

For storage size alternative, comparison matrix is shown in Table 10, and the computer simulation results of the weightage for size alternative are shown in Figure 7.

($e_{\max}$: 4; CI: 0; CR: 0 < 0.1)

Table 10: Pairwise comparisons between storage size alternative

	A_1	A_2	A_3	A_4
A_1	1	1	1/2	1
A_2	1	1	1/2	1
A_3	2	2	1	2
A_4	1	1	1/2	1
Sum	5	5	2.5	5

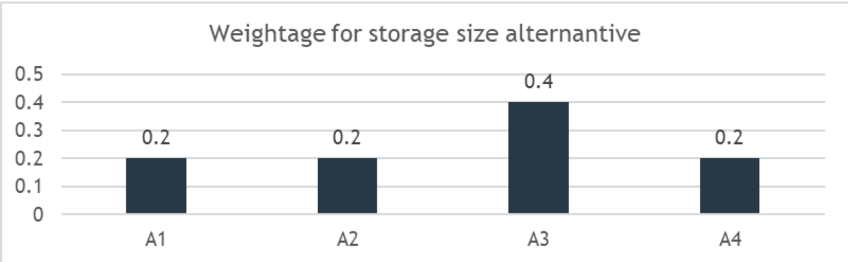

Figure 7. Computer simulation results of the weightage for size alternative

For screen size and resolution alternative, comparison matrix is shown in Table 11, and the computer simulation results of the weightage for screen size and resolution alternative are shown in Figure 8.

($e_{\max}$: 4; CI: 0; CR: 0 < 0.1)

Table 11: Pairwise comparisons between screen size and resolution alternative

	A_1	A_2	A_3	A_4
A_1	1	1	1	1
A_2	1	1	1	1
A_3	1	1	1	1
A_4	1	1	1	1
Sum	4	4	4	4

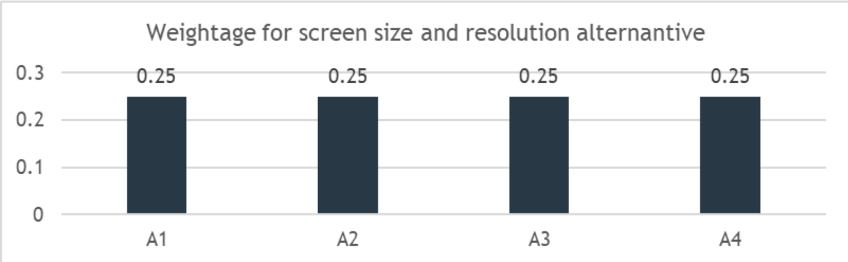

Figure 8. Computer simulation results of the weightage for screen size and resolution alternative

For weight alternative, comparison matrix is shown in Table 12, and the computer simulation results of the weightage for weight alternative are shown in Figure 9.

($e_{\max}$: 4; CI: 0; CR: 0 < 0.1)

Table 12: Pairwise comparisons between weight alternative

	A_1	A_2	A_3	A_4
A_1	1	1	1	1
A_2	1	1	1	1
A_3	1	1	1	1
A_4	1	1	1	1
Sum	4	4	4	4

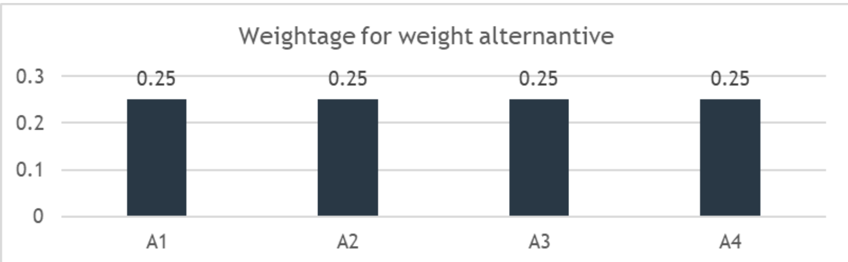

Figure 9. Computer simulation results of the weightage for weight alternative

As illustrated in Table 13, each row is added together to determine the final weightage of each alternative by multiplying the weightage of the alternatives by the weightage of the criteria. The alternatives are ranked as $A_2 > A_4 > A_1 > A_3$ according to the computer simulation results for the final weightage of each alternative, which can be seen in Figure 10. As a result, Alternative 2 is found to be the best alternative.

Table 13: Result for final weightage for each alternative

Alternative	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Final Weightage
Criteria weightage	0.1942	0.0670	0.1790	0.1942	0.1215	0.1820	0.0619	
A_1	0.1892	0.3589	0.25	0.25	0.2	0.25	0.25	0.2394
A_2	0.3507	0.3589	0.25	0.25	0.2	0.25	0.25	0.2708
A_3	0.1093	0.0819	0.25	0.25	0.4	0.25	0.25	0.2296
A_4	0.3507	0.2003	0.25	0.25	0.2	0.25	0.25	0.2602

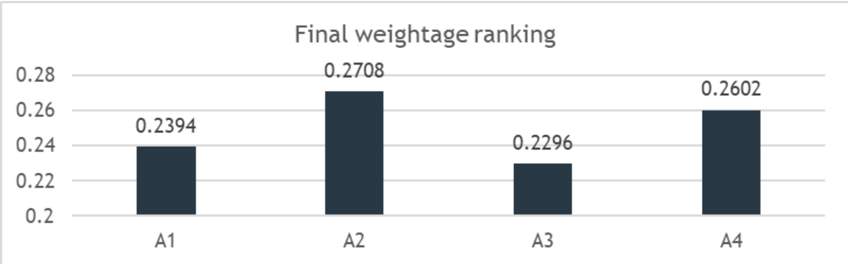

Figure 10. Computer simulation results of the final weightage

3.1 Results

All steps are carried out for each respondent, using their top criteria and alternatives. Tables 14 and 15 below show a summary of the average and weightage results for each criterion and alternative for all respondents.

Table 14: Average and weightage for criteria

Criteria	Average	Percentage (%)
C_1	0.1523	17.03
C_2	0.1329	10.04
C_3	0.1495	14.41
C_4	0.1551	17.90
C_5	0.1298	12.23
C_6	0.1718	21.40
C_7	0.1091	6.99

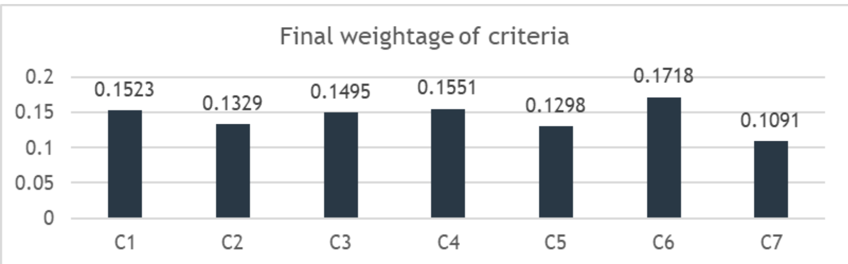

Figure 11. Computer simulation results for the final weightage of criteria

Table 15: Average and weightage for alternative

Alternative	Average	Percentage (%)
A_1	0.1983	10.81
A_2	0.2715	28.83
A_3	0.2344	15.32
A_4	0.2932	45.05

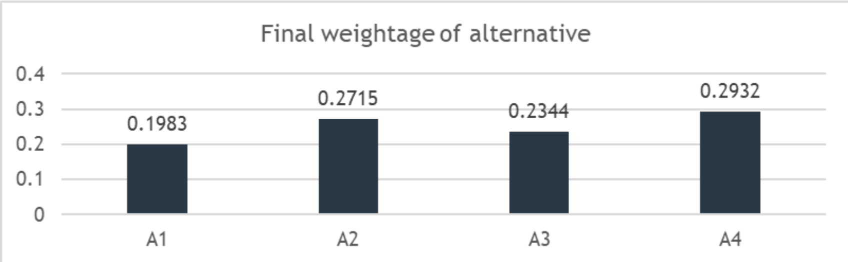

Figure 12. Computer simulation results for the final weightage of alternative

4. Discussion

The outcomes of the study show the most important criteria in the selection of gadgets. As a result of the results of this study, the most important criterion is storage size. As a result of the results of this study, the most important criterion is storage size, C_6, with a weightage of 0.1718, with the majority of respondents preferring storage size when selecting criteria. People desired to do business for a long period of time and charge less, so this criterion was considered years later. As a result, the greater the battery's capacity, the higher the demand because it allows for more time to utilise the gadgets. Alternative 4, with a weightage of 0.2932, which is a smartphone, is the most preferable gadget among the alternatives. It demonstrated that students and lecturers used smartphones because access to training and reference materials available on local networks and the Internet is made quick and easy. Without the use of additional devices, educators and students can always access the necessary reference material (Kabanova & Vetrova, 2019). We can discover the most significant criterion and the most preferable alternative from this study, which was conducted using the AHP method. Criteria 6, C_6, which is the storage size, and Alternative 4, A_4, which is a smartphone, are the most essential criteria and alternatives, according to our study.

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7. Conflict of Interest

The authors have no conflicts of interest to declare.

8. References

Enrique Mu, M. P.-R. (2018). Practical Decision Making An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions v2. In Журнал Органической Химии (Issue 9). https://doi.org/10.7868/s0514749218090182

Kabanova, E. E., & Vetrova, E. A. (2019). Published in the Slovak Republic European Journal of Contemporary Education E-ISSN. European Journal of Contemporary Education, 8(3), 524–533. https://doi.org/10.13187/ejced.2019.3.524

Liu, Y., Eckert, C. M., & Earl, C. (2020). A review of fuzzy AHP methods for decision-making with subjective judgements. Expert Systems with Applications, 161, 113738. https://doi.org/10.1016/j.eswa.2020.113738

Obioma Ejimabo, N. (2015). AN APPROACH TO UNDERSTANDING LEADERSHIP DECISION MAKING IN ORGANIZATION. European Scientific Journal, 11(11).

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. Mathematical Modelling, 9(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8

Taherdoost, H. (2018). Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach. Journal of Economics and Management Systems, 2(International), 244–246.