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Ranking and Selection of the Best Laptop Model by Using Multiple Criteria Decision Making (MCDM)Methods

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Abstract

Nowadays, in this modernization era of the 21st century, telecommunication has become a huge part of our daily lives. This has come into terms as almost everyone in this world uses electronic devices to communicate with each other which includes devices such as mobile phones, tablets, computers and personal computers. At the present time, personal computers or laptops have become one of the most important tools in a lot of daily life activities including communication, education, entertainment and work. A lot of people of all ages ranging from students, educators, children, employees and employers use personal computers to execute their tasks. The main objective of this research is to study and determine the best laptop model for university students by taking four criteria into consideration which are technical conditions, functionality conditions, physical conditions and price where each criterion has its own sub-criteria. By using three Multiple Criteria Decision-Making (MCDM) methods, this research is able to come up with a conclusion of choosing the most suitable laptop model for university students. The first MCDM method is the Analytic Hierarchy Process (AHP) method which is used to determine the weightage of each criterion and sub-criteria of the laptop models. This research then proceeds to use two other MCDM methods which are Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method and Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE). These methods are able to assist in making pair-wire comparisons thus helping decision makers develop a final decision through the calculation of each alternative's priority value. Through the application of these three methods, Laptop 5 would be selected as the best and most suitable laptop model for university students. In this research, Microsoft Excel is used to assist in certain associated calculation processes.

Keywords: Ranking and Selection; Laptop; MCDM Methods

1. Introduction

Decision making is a common everyday life task that everyone eventually needs to carry out at some point in their day or life. This action involves someone to carry out evaluation, analysation and consideration towards a number of different options or choices in order to come up with the best or most compatible decision depending on situations. Decision making could be as simple as choosing what to eat for lunch amongst multiple different options ranging from Indian food, Western food, Chinese food and Malay food. However, it could also be as complicated as deciding on purchasing a house which involves multiple different characteristics to be considered such as location, cost, size of the house, number of bedrooms and bathrooms and even car porch. This shows that not every decision-making task is as straightforward and easy as determining what to eat for lunch or dinner. Therefore, this task needs to be assisted by a more advanced approach in order to make it possible for the best decision to be made in certain situations. This is where operational research comes into the picture.

Operational research is a scientific analytical method used to aid in problem-solving and decision making. It is an essential area of Mathematics which is used as a tool for decisions to be made when it involves complicated procedures which comprises multiple different characteristics and options

to be considered, evaluated and analysed with. These various different choices are the elements that make making decisions be complex in certain situations.

In this era of modernization, it is fair to say that it is almost impossible for anyone to survive in the fast pace world without the help of electronic devices. Electronic devices ranging from television, camera, iron, microwave, air conditioner, mobile phones and even coffee machine are now part of our daily essentials. Each of these electronic devices play significant roles in making our everyday lives easier from making us coffee in the morning to heating our food to washing our clothes at the end of the day. That being said, one of the most important electronic devices that need to be owned by people of many stages of lives is laptop or also known as personal computer. Laptop is a portable version of a desktop computer that was built to be more convenient for users to bring it anywhere at any time. They include a number of hardware that serves the same roles as the ones in desktop computers which include a screen, keyboard and a trackball which serves as the mouse for the laptop [3]. T

The fast pace of electronic devices evolution plays a huge role in education assistance which includes portable communicative devices such as tablets, mobile phones and laptops. Therefore, it is most definitely relevant to say that every university student is compulsory to possess their own laptop model. This is due to the fact that almost every educational procedure involves the use of technology and electronic devices such as mobile phones, internet browsing and laptops. In accordance to that, it is very important for a student to be able to make the best choice for the type of laptop model to be purchased before pursuing their education journey in universities. However, students face issues in making decisions on which laptop model to purchase as there are a lot of different criteria and options to be taken into consideration in choosing the best one. Laptops also come in variety of brands and specifications such as technical conditions, functionality conditions, physical conditions and price. It must also be noted that students come from variety of family backgrounds, economic stability and financial situations which influence the affordability factor for them to purchase electronic devices, Therefore, price range of laptop models definitely plays one of the biggest roles in affecting the overall results of the ranking and choosing for the best laptop models towards university students. This thesis aims to study, analyse and find solutions in making the best decision of laptop selection for students by using Multi Criteria Decision Making (MCDM) methods which include several different subjects that are; AHP, MAUT, TOPSIS, ELECTRE, PROMETHEE and GP. By using these methods, this study will be able to help university students to choose the best and most compatible laptop model to be purchased by them for their education.

2. Literature Review

2.1 Multiple Criteria Decision Making (MCDM) Methods

2.1.1. Weighted Product Model (WPM)

The Weighted Product Model is an MADM problem that evaluates several alternatives to a set of attributes or criteria, in which each attribute is independent of each other [8]. It applies techniques of multiplication in order to attribute the attribute rating. The rating of each attribute for this case must be in advance with the corresponding attribute weights which is similar process to the normalization process.

2.1.2. Analytical Hierarchy Process (AHP)

AHP uses Saaty's scale which allows any qualitative or even quantitative data to be evaluated and weighted using scales by decision makers. Saaty's scale is a weighted scale which allows users and decision makers to make judgement towards a particular criteria or options regarding to a decision. Their judgements will then be classified using a scale system called the Saaty's scale which ranges from 1-9 representing the most preferred to the most unpreferred option for a decision-making process.

2.1.3 Multi Attribute Utility Theory (MAUT)

Multi Attribute Theory (MAUT) method is also a very well-known method to be used in the field of decision making. Same as to the AHP method, MAUT also utilizes the system of pairwise comparison where the judgement and opinions of decision makers play a role in quantitative weighting of criteria in a decision-making process. This method is a good alternative to be utilized in a decision-making process. In a study conducted by Josias Zietsman, Laurence R. Rilett and Seung-Jun Kim (2006), out of three decision making methodologies used to identify appropriate performance measures for sustainable transportation and quantify the measures with a traffic simulation model (CORSIM), MAUT method was found to be the best due to its availability to include broad range of quantitative and qualitative sustainability issues in its decision-making process [10].

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

Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) is a method that is often used in the field of Mathematics to resolve problems of MCDM. It has a ton of uses that has been applied by various different fields. This includes a number of applications and practice such as financial ration performance within a specific industry, comparison of company performances and financial investment in advanced manufacturing systems [12]. Despite TOPSIS being useful and beneficial, it also has its own disadvantages and limitations. Mainly, the issue that often is related to this method revolves around its sensitivity of R value. The work on the improvement of original TOPSIS method R value has mainly emphasized on its weight and formula. A newer and modified version of TOPSIS called modified TOPSIS (M-TOPSIS) has been created to accommodate this issue. However, this study will not include this method of decision making.

2.1.5. Elimination and Choice Translating Theory (ELECTRE)

Elimination and Choice Translating Theory or ELECTRE is a method designed to aid multiple criteria decision process. The ELECTRE family methods consist of a few different methods that use as a preference model an outranking relation on the set of actions – it is constructed in result of concordance and nondiscordance tests involving a specific input preference information [14].

2.1.5. Preference Ranking Organization Method for Enrichment of Evaluation (PROMETHEE)

PROMETHEE is a multicriteria decision making method that was developed by Bran et. al. (1986). It is quite a simple ranking method in conception and application compared to other methods in MCDM analysis. It has the ability to adapt to problems with finite number of alternatives that are to be ranked taking into account several conflicting or non-conflicting criteria [17].

2.2. Strengths and Weaknesses of MCDM Methods

Table 1: Strengths and Weaknesses of MCDM Methods

Method	Strengths	Weaknesses
Weighted Product Model (WPM)	- Can eliminate any element to be measured - Utilize proportional values instead of real (actual) ones	- Do not provide any solution with equal decision matrix (DM) weight
Analytical Hierarchy Process (AHP)	- Calculates the inconsistency index which is important t ensure consistent judgements of decision makers - Quick application compared to other methods - Converts complex problems into simple, flexible and intuitive hierarchy	- Loss of information due to high level of aggregation - Difficulty to interpret qualitative scale due to human nature - Accuracy can vary widely in subjective problems
Multi Attribute Utility Theory (MAUT)	- Takes uncertainty into account - Can incorporate preferences	- Need a lot of input - Preferences need to be precise

Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	- Only depends on the weights and intrinsic characteristics of each alternative - Consistent and reliable - Easy to implement and understandable principle	- Loss of information due to high level of aggregation - Does not clarify how to determine the weights for different criteria - The use of Euclidean distance does not consider the correlation of attributes
Elimination and Choice Translating Theory (ELECTRE)	- Applicable even when information is missing - It can use qualitative and quantitative data - Weights are used as coefficients of importance so that compensation is not implied	- Very long computation process compared to other MCDM methods - Only draws attention to preference and ignores the level of difference between alternatives
Preference Ranking Organization Method for Enrichment of Evaluation (PROMETHEE)	- It is easy to use and of low complexity - It is particularly useful when there are difficulties in reconciling alternatives - Can use qualitative and quantitative data	- Concerns on the dependence of quite arbitrary definitions of what constitutes outranking and lack of axiomatic bases - Very long computation process compared to other MCDM methods - It is difficult for users to get a clear view of the problem when using many criteria
Goal Programming (GP)	- Capable of handling large-scale problems - Can produce infinite alternatives	- Its ability to weigh coefficients typically needs to be used in combination with other MCDM methods

2.3 Criteria in Ranking and Choosing Laptop Model

Firstly, technical conditions comprise of a number of sub-criteria that revolves the technicalities of the laptop model. These sub-criteria consist of three different elements which are Solid State Drive (SSD), Random-Access Memory (RAM) and Graphics Processing Unit (GPU). Apart from that, functionality conditions of a laptop model revolve around a number of elements which include; Display Type (DT), Operating System (OS) and camera quality. Next, another criterion of laptop models that is included in this study is physical conditions. Physical condition of laptop models comprises of a few elements which are; Display Size (DS), Laptop Size (LS) and Laptop Weight (LW). Lastly, the arguably most important and looked into criterion when purchasing a laptop model by users is the price of laptop model.

3. Methodology

3.1. Data Collection

In order to get first hand data from decision makers of the ranking and choosing of laptop model, an online survey is distributed to 100 Mathematics and Industrial Mathematics students of UTM. This survey allows users to evaluate and rank each criterion and sub-criteria of five different laptop models; Laptop 1, Laptop 2, Laptop 3, Laptop 4 and Laptop 5. The model and brand of each laptop is kept anonymous. This serves a purpose to prevent any biasness from students as brands play a huge role in determining a person's first impression towards something. The survey utilizes Saaty's 9-point scale. This allows qualitative data to be converted into quantitative data in order to find the weightage of each criterion of the laptop models. Through the survey answered by 100 students, data is collected and processed by using three different MCDM methods which are AHP, TOPSIS and PROMETHEE. These methods will allow the process of analysing the collected data, thus is continued with the ranking of the laptop models in accordance to the weightage of each criterion answered by the university students through the distributed online survey.

3.2. Multiple Criteria Decision Making (MCDM) Methods

Multiple Criteria Decision Making (MCDM) method is a widely used mathematical tool in order to solve decision making problems of more than one involved criterion. It involves a large range of methods which has each of their own procedures, steps and data processing. This study has presented brief description and introduction of seven MCDM methods in Chapter 2. Continuing this research, three of the mentioned MCDM methods are used in analysing the collected data of this study which are Analytical Hierarchy Process (AHP), Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) and Preference Ranking Organization Method for Enrichment and Evaluation (PROMETHEE).

3.2.1 Analytical Hierarchy Process (AHP)

Construct the pairwise comparison into square matrix with diagonal elements of 1.

$$\begin{pmatrix} 1 & a_{12} & a_{13} \\ a_{21} & 1 & a_{23} \\ a_{31} & a_{32} & 1 \end{pmatrix}$$

Convert the fractional value into decimal. Then, determine the sum of each column of the reciprocal matrix and calculate the normalized pairwise matrix by dividing all elements of the column with the sum of their column. The criteria weight is then evaluated by averaging all elements in the row. Check for consistency using the formula below.

C.I. = $\frac{\lambda_{max}}{n-1}$; where n is the number of compared elements (1)

C.R. = $\frac{Consistency\ Index\ (C.I.)}{Random\ Index\ (R.I.)}$ (2)

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

An element, r_{ij} of the normalized decision matrix R can be calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{M} x_{ij}^2}} \quad (3)$$

A set of weights W = (w_1, w_2, w_3, …, w_N), defined by the decision makers is accommodated to the decision matrix to generate the weighted normalized matrix V as follows.

$$V = \begin{bmatrix} w_1 r_{11} & \cdots & w_N r_{1N} \\ \vdots & \ddots & \vdots \\ w_1 r_{M1} & \cdots & w_N r_{MN} \end{bmatrix} \quad (4)$$

The ideal A^* and the negative-ideal A^- solutions are defined as follows:

$$A^+ = \left\{\left(\max v_{ij} \,\middle|\, j \in J\right), \left(\min v_{ij} \,\middle|\, j \in J\right) \middle|\, i = 1,2,3, \dots, M\right\} \quad (5)$$

$$= \{v_1, v_2, \dots, v_N)$$

$$A^+ = \left\{\left(\min v_{ij} \,\middle|\, j \in J\right), \left(\max v_{ij} \,\middle|\, j \in J\right) \middle|\, i = 1,2,3, \dots, M\right\} \quad (6)$$

$$= \{v_1, v_2, \dots, v_N)$$

N-dimensional Euclidean distance method is applied in order to measure the separation distance of each alternative to the ideal solution and negative-ideal solution.

$S_{i^*} = (\sum v_{ij} - v_{j^*})^2)^{1/2}$, i = 1, 2, 3, …, M, (7)

Where S_{i^*} is the separation of each alternative from the ideal solution.

$S_{i^-} = (\sum v_{ij} - v_{j^*})^2)^{1/2}$, i = 1, 2, 3, …, M, (8)

Where S_{i-} is the separation distance of each alternative from the negative-ideal solution

The relative closeness of an alternative Ai with respect to the ideal solution A* is defined as follows:

$C_{i^*} = S_{i^*} / (S_{i^*} + S_{i-}), 0 \leq C_{i^*} \leq 1, i = 1, 2, 3, \ldots, M$ (9)

Where $C_{i^*} = 1$ if $A_i = A^*$, and $C_{i-} = 0$ if $A_i = A^-$.

The best alternative can now be decided through ranking all alternatives according to preference order of C_{i^*}. The best alternative is the one that has the shortest distance from ideal solution and the longest distance from the negative-ideal solution.

3.2.6 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

To normalize the evaluation matrix, formulas for beneficial criteria (direct category) and non-beneficial criteria (indirect category) as shown below are used respectively.

$$Rij = \frac{[xij - \min(xij)]}{[\max(xij) - \min(xij)]} \quad (i = 1,2, \ldots, m; j = 1,2, \ldots, n) \tag{10}$$

$$Rij = \frac{[\max(xij) - xij]}{[\max(xij) - \min(xij)]} \quad (i = 1,2, \ldots, m; j = 1,2, \ldots, n) \tag{11}$$

The difference between each normalized value of each criterion for each alternative is calculated. The calculation is carried out as shown in the example below.

Table 2: Dummy Table of Alternative and Criteria

Attribute / Criteria / **Alternative**	Criteria 1	Criteria 2	Criteria 3
Alternative 1	a	b	c
Alternative 2	d	e	f
Alternative 3	x	y	z

Assuming Alternative 1 is A1, Alternative 2 is A2, Alternative 3 is A3 and D represents evaluative differences of i^{th} alternative with respect to other alternatives.

Table 3: Calculation of Dummy Table of Alternative and Criteria

Evaluative Differences	Criteria 1	Criteria 2	Criteria 3
D(A1 – A2)	a - d	b - e	c – f
D(A1 – A3)	a - x	b - y	c – z
D(A2 – A1)	d - a	e - b	f – c
D(A2 – A3)	d - x	e - y	f – z
D(A3 – A1)	x – a	y - b	z – c
D(A3 – A2)	x - d	y - e	z - f

Using the preference values and weightage of criteria, the summation of the product of each preference value with its weightage is divided with total weightage as displayed in the formula below.

$$\text{Aggregated preference function} = [\sum_{j=1}^{n} \text{wjPj(a, b)}] / \sum_{j=1}^{n} \text{wj} \tag{12}$$

Determine the Entering Flow and Leaving Flow by calculating the average summation of the aggregated preference functions. By referring to the leaving flows and entering flows calculated in Step 5, the net outranking flow can then be determined. This can be done by subtracting Leaving flow to the Entering flow. Once the net outranking flow of each alternative has been calculated, we can finally form a preference ranking.

4. Results and discussion

This chapter analyses and discusses the results obtained for this research through surveying method. Upon executing the objectives of this research, an online survey has been distributed towards 100 Mathematics and Industrial Mathematics students of Universiti Teknologi Malaysia. This serves as an effort to take every student's personal preference and opinion into consideration when it comes to choosing the most suitable laptop model for their use. The survey distributed is prepared and divided into four main parts which are the criteria of the laptop model itself; technical conditions, functionality conditions, physical conditions and price. Each of these criteria has its own sub-criteria where in technical conditions, it has 3 sub-criteria that includes Solid State Drive (SSD), Random Access Memory (RAM) and Graphics Processing Unit (GPU). In functionality conditions, it has 3 sub-criteria of Display Type (DT), Operating System (OS) and Camera Quality (CQ). Whereas in physical conditions, this criterion also has 3 sub-criteria which includes Display Size (DS), Laptop Size (LS) and Laptop Weight (LW). For the criteria of price, it does not have any sub-criteria as it is its own main attribute.

Table 4: Laptop Model's Criteria and Sub-Criteria

Criteria	Sub-Criteria	Alternative
Technical Condition (TC)	SSD	HP 245 G8 Notebook PC
	RAM	
	GPU	ASUS Vivobook Go 14 E410
Functionality Condition (FC)	DT	
	OS	Huawei MateBook D15
	CQ	
Physical Condition (PC)	DS	Lenovo IdeaPad Slim 1i 14
	LS	
	LW	Acer Swift 1 SF114-34
Price		

4.1 The AHP Method for Criteria Weightage Evaluation

This part of the research utilizes the AHP method to analyse and calculate the weightage of each criterion and sub-criteria for the laptop models. By using the Saaty's 1-9 scale, preference of each criterion and sub-criteria is placed. These preference values allow for the construction of pairwise comparison tables. All results of the obtained priority weight values are displayed in graphs below.

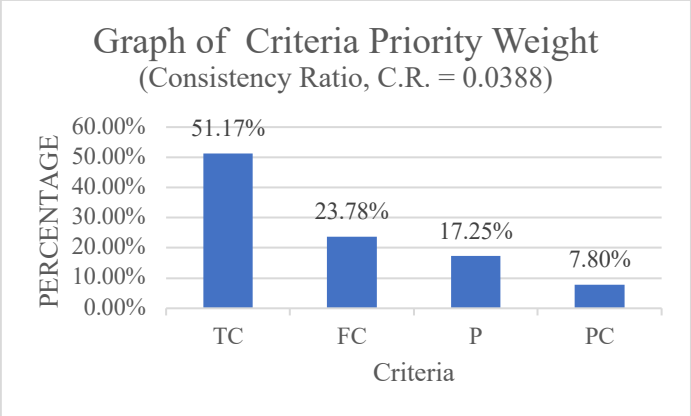

Figure 1 Priority Weights for All Four Criteria

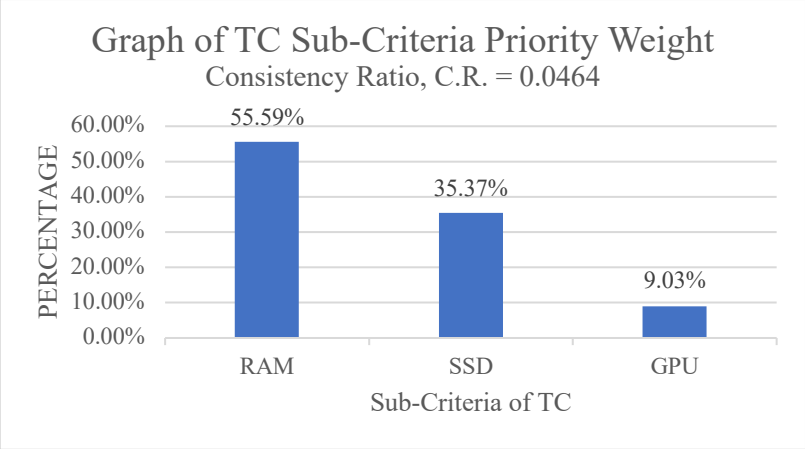

Figure 2 Priority Weights of TC Sub-Criteria

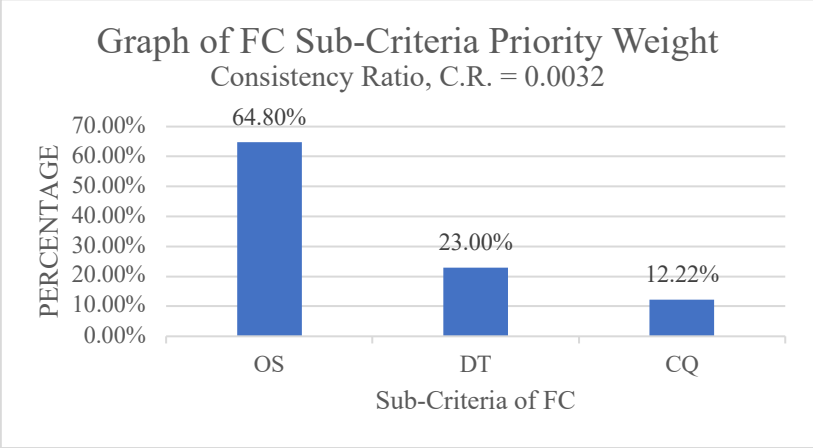

Figure 3 Priority Weights of FC Sub-Criteria

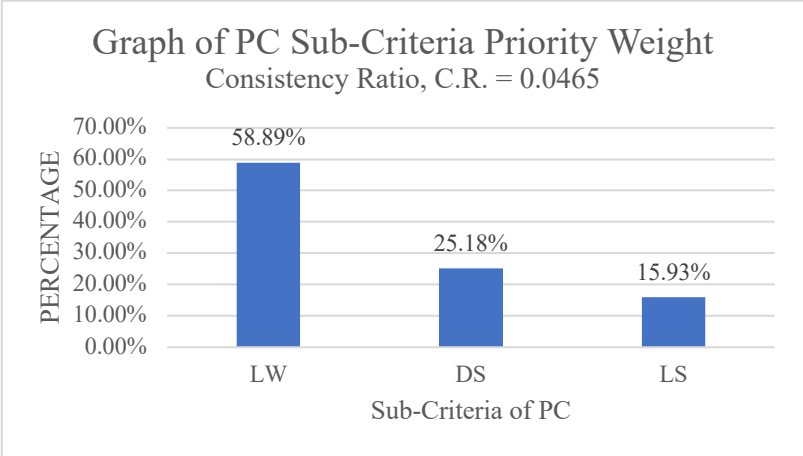

Figure 4 Priority Weights of C Sub-Criteria

4.2 The TOPSIS Method for Laptop Model Ranking and Selection

This research continues its study and analysis by utilizing the method of Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) in order to rank and select the best laptop model for university students. This method starts with the decision matrix of sub-criteria of the four main criteria. By using

the TOPSIS method, each sub-criteria decision matrix will have their own ranking of laptop models based on the sub-criteria only. Using the obtained ranking of laptops, decision matrix of all four main criteria can be formed, thus allowing the final calculation process of determining the ranking of laptop models based on the main criteria. In these decision matrix, quantitative data are left as is. For qualitative data, they are converted to quantitative data using where 1: BAD, 2: BELOW AVERAGE, 3: AVERAGE, 4: GOOD and 5: EXCELLENT. The values are determined by preferences of Mathematics and Industrial Mathematics students of UTM from the distributed survey answered by them.

Table 5: Ranking of Laptop Models based on AHP Method

Laptop Model	S_i^+	S_i^-	P_{ij}	Ranking
L1	0.1375	0.2780	0.6691	2
L2	0.2094	0.1623	0.4366	4
L3	0.2052	0.1399	0.4054	5
L4	0.2833	0.2395	0.4581	3
L5	0.0900	0.2351	0.7232	1

Therefore, based on all calculations using each required step of TOPSIS method, it is concluded that the best and most suitable laptop model for university students is **Laptop 5** which is the model of Acer Swift 1 SF114-34.

4.3 The PROMETHEE Method for Laptop Model Ranking and Selection

This research continues its studies by utilizing another MCDM method which is the PROMETHEE method. This is to investigate whether two different methods produce the same final conclusion or otherwise. Same as the TOPSIS method, this method starts with finding out the rankings of laptop models obtained from the decision matrix of sub-criteria of each criterion. Once the rankings are obtained, a decision matrix of the main criteria can be formed, thus allowing the process of determining the overall ranking of laptop models based on their four main criteria.

Table 6: Ranking of Laptop Models based on PROMETHEE Method

Alternatives	φ^+	φ^-	φ	Ranking
L1	0.3063	1.5723	-1.2660	5
L2	1.2567	0.5439	0.7128	2
L3	0.9277	1.0008	-0.0731	3
L4	0.6858	1.6361	-0.9503	4
L5	1.8240	0.2474	1.5766	1

Therefore, based on the calculations of PROMETHEE method, it is observed that the laptop model that is ranked as the best and most suitable laptop model to be used by university students is **Laptop 5.** This decision is made by considering all main criteria including each of their own sub-criteria. The best laptop model based on the PROMETHEE method is Acer Swift 1 SF114-34.

Conclusion

In this study, five laptop models are involved; Laptop 1: HP 245 G8 Notebook PC, Laptop 2: ASUS Vivobook Go 14 E410, Laptop 3: Huawei MateBook D15, Laptop 4: Lenovo IdeaPad Slim 1i 14 and Laptop 5: Acer Swift 1 SF114-34. These laptop models are made anonymous in order to avoid biasness in the process of collecting data for preferences input through survey distribution towards 100 Mathematics and Industrial Mathematics students of UTM. By using TOPSIS method, the laptop model that is ranked as the best is **Laptop 5** which is the **Acer Swift 1 SF114-34** model. On the other hand, the PROMETHEE method also gives out the same conclusion where the best and most suitable laptop model is **Laptop 5**. This hence shows that **Acer Swift 1 SF114-34** is the most suitable laptop model for students by taking four main criteria into consideration which include Technical Conditions (TC), Functionality Conditions (FC), Physical Conditions (PC) and Price (P).

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