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OUTRANKING METHODS: PROMETHEE I AND PROMETHEE II

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Abstract: This article highlights the application of the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) I and II in selecting the best laptop model among six different available models in the market. Seven important criteria, that is, processor, hard disk capacity, operating system, RAM, screen size, brand, and color, are selected, based on which the selection process have been made. Analytic hierarchy process (AHP) is adopted for calculating the weightages of the seven criteria and PROMETHEE is applied to select the best alternative. PROMETHEE I provides the partial ranking and preferences of one model over another, whereas PROMETHEE II provides the complete ranking of the alternatives. From this analysis, Model 4 is coming out to be the best laptop model occupying the first position and Model 1 occupies the last position, thus indicating it as the worst model among the group. The objectives of this article are to select the best laptop model among six available alternatives and to understood the steps of both multiple criteria decision-making (MCDM) methodologies, that is, PROMETHEE and AHP, in details.

Keywords: PROMETHEE I, PROMETHEE II, AHP, MCDM, laptop models.

JEL Classification: C61, C83, D81, M11.

1 Introduction

In this 21st century, computer has become one of the most essential electronics gadgets in our daily life. It makes our life easier and faster as compared to 15 years ago. In 2018, approximately 259.39 million of PCs were shipped around the world (Holst, 2019). Table 1 shows the global PC units' shipment from 2006 to 2018 (Statista, 2019).

Table 1. Global PC units' shipment from 2006-2018 (*Source:* Statista, 2019)

Year	Shipments in millions
2018	259.39
2017	262.68
2016	269.72
2015	287.68
2014	313.68
2013	316.46
2012	351.06
2011	365.36
2010	350.90
2009	308.34
2008	290.80
2007	272.45
2006	239.21

Moreover, with the technological development laptops are replacing the desktop computers and occupying the markets more rapidly because of their portability and ease of use. At present, there are six major laptop manufacturing companies in the market, that is, Lenovo, HP, Dell, Acer, Asus, and Apple. These brands have thousands of models out there in the market with different specifications, so it is very much important to select the appropriate laptop model so that most of our requirements can be fulfilled. Such an initiative is taken and presented in this article, where the best laptop model is proposed among six different models actually available in the market from different brands having different specifications by applying outranking methods the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) I and II. The selected six laptop models and their specifications are presented in Table 2.

In this present analysis, six different laptop models having different configurations are selected from the market, which are presented in Table 2, and the aim of this research work is to propose the best model among them based on seven major criteria, that is, processor, hard disk capacity, operating system, RAM, screen size, brand, and color. After doing some research work, it is found that these models are in high demand and are generally preferred by most of the customers. The weightages of the criteria are found by analytic hierarchy process (AHP) and then PROMETHEE is applied by using those weightages to select the best model. Two categories of PROMETHEE are used in this article, where PROMETHEE I depicts the preferences of one model over another and PROMETHEE II helps to propose the complete ranking of the alternatives indicating from best to worst model.

Table 2. Selected laptop models and their configurations
(*Source:* Online shopping Websites and electronic stores)

Models	Processor	Hard Disk Capacity	Operating System	RAM	Screen Size	Brand	Color
Model 1	I3	512GB	DOS	4GB	14 Inch	HP	Black
Model 2	I5	1TB	Linux	4GB	15.6 Inch	Acer	Black
Model 3	I5	2TB	Windows	8GB	15.6 Inch	Lenovo	Gold
Model 4	I7	2TB	Windows	16GB	17.3 Inch	Asus	Silver
Model 5	I5	1TB	Windows	8GB	15.6 Inch	HP	Silver
Model 6	I3	512GB	Linux	4GB	15.6 Inch	Dell	Black

2 Literature Review

For many years, multiple criteria decision-making (MCDM) proves to be a very useful tools for taking effective decision in the fields of water management (Qin, et al., 2008), waste management (Chandrakar and Limje, 2018), industries (Bentes, et al., 2012; Bulut, et al., 2012; Celik, et al., 2009; Duran and Aguilo, 2008; Roistamzadeh and Sofian, 2011; Sri Krishna, et al., 2014), business and finance (Albadvi, et al., 2007; Korhonen, et al., 2006; Lee, et al., 2008), medical and health sector (Buyukozkan and Cifci, 2012), education (Bhattacharya and Chakraborty, 2014; Melon, et al., 2008), environmental management (Geldermann, et al., 2000; Marzouk and Abdelakder, 2019; Vaillancourt and Waaub, 2004), energy management (Kowalski, et al., 2009; Tsoutsos, et al., 2009), and so on. Many researchers implemented various MCDM techniques in different areas for strategic decision making. Some of the most popular MCDM techniques include AHP (Saaty, 1980; 2001; 2008; 2010), PROMETHEE (Brans, 1982; Brans, et al., 1984; 1986; Brans and Vincke, 1985), ELimination Et Choix Traduisant la REalité (ELECTRE) (Roy, 1968), Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) (Brauers and Zavadskas, 2006; 2009), The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang, et al., 1993; Hwang and Yoon, 1981; Yoon, 1987), COmplex PRroportional ASsessment (COPRAS) (Zavadskas, et al., 2008), Additive Ratio ASsessment (ARAS) (Zavadskas, et al., 2010; Zavadskas and Turkis, 2010), and Fuzzy Analytic Hierarchy Process (FAHP) (Ayhan, 2013; Buckley, 1985; Chang, 1996; Zadeh, 1965). This section mainly includes some literatures (Behzadian, et al., 2010; Jayant and Sharma, 2018) of the researchers adopting PROMETHEE and AHP methods for decision-making purposes in various fields.

Geldermann, et al. (2000) considered a case study in iron- and steel-making industry where the outranking method PROMETHEE was adopted for environmental assessment. Goumas and Lygerou (2000) applied PROMETHEE method for the evaluation and ranking of alternative energy exploitation schemes of a low-temperature geothermal field under fuzzy environment. Ngai and Chan (2005) applied analytic hierarchy process to select the most appropriate support knowledge management tool. Bertolini, et al. (2006) selected the best discount in defining a proposal for a public work contract by implementing AHP as a tool. Albadvi, et al. (2007) developed a decision-making model in their article for selecting superior stocks in stock exchange by using PROMETHEE method. Wang and Yang (2007) evaluated the information systems (IS) outsourcing problems using hybrid approach of AHP and PROMETHEE by considering six factors, where AHP was used to analyze the structure of the outsourcing problem and determine weights of the criteria and PROMETHEE method was used for final ranking of the alternatives.

Melon, et al. (2008) adopted AHP to evaluate the proposals for educational innovation projects to help the Institute of Educational Sciences of the Polytechnic University of Valencia to choose the best educational project. Tsoutsos, et al. (2009) determined a set of energy planning alternatives based on economic, technical, social, and environmental criteria factors by implementing PROMETHEE methodology for the sustainable energy planning on the island of Crete in Greece. Alomoush (2010) selected the best optimal location of thyristor-controlled series compensator (TCSC) in a transmission system using PROMETHEE MCDM process. Turcksin, et al. (2011) proposed an integrated approach of AHP and PROMETHEE for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet. Yilmaz and Dagdeviren (2011) used a combined approach of fuzzy-PROMETHEE and zero-one goal programming model for solving welding machine selection problem of a company.

Peng and Xiao (2013) considered a material selection problem for a journal bearing in which PROMETHEE combined with analytic network process (ANP) is presented; ANP was used to identify the weights and PROMETHEE was used to rank alternatives. Zhao, et al. (2013) proposed a modified PROMETHEE method to improve the efficiency and response time in incident management. Kabir and Sumi (2014) considered a case study from Bangladesh where fuzzy-AHP and PROMETHEE were used to select the power substation location. Kucharski (2014) used PROMETHEE method to rank selected types of investment funds offered on the polish market. Maletic, et al. (2014) applied AHP for the selection of maintenance policy. Kilic, et al. (2015) performed an analysis on the enterprise resource planning (ERP) selection problem for the small medium enterprises (SMEs) in Istanbul, Turkey, by combining AHP-PROMETHEE hybrid MCDM methodology.

Polat (2016) used integrated AHP-PROMETHEE methods for selecting the most appropriate subcontractor to be worked within an international construction project, where AHP was used to analyze the structure of the subcontractor selection problem and to determine the weights of the criteria and PROMETHEE was used to obtain complete ranking and perform sensitivity analysis by changing the weights of criteria. Polat, et al. (2016) proposed an integrated approach of AHP and PROMETHEE to help a Turkish construction company in selecting the appropriate urban renewal project by finding the weights of the selected criteria and to rank the alternative projects, respectively. Nikouei, et al. (2017) used PROMETHEE based on MCDM approach for selecting the best membrane prepared from sulfonated poly(ether ketone)s and poly(ether sulfone)s, and the final results showed that poly(ether ketone) membranes in selected criteria were better than poly(ether sulfone) membranes. Nourbakhsh and Yousefi (2017) proposed the best indicator water quality parameters using AHP in order to manage the ground water quality. Butowski (2018) developed an integrated AHP and PROMETHEE approach to evaluate the attractiveness of European maritime areas for sailing tourism. Naserizade, et al. (2018) developed a new stochastic model based on conditional value at risk (CVaR) and multi-objective optimization methods for optimal placement of sensors in water distribution system (WDS), and finally, PROMETHEE was used to determine the best solution and to rank the alternatives on the trade-off curve among objective functions.

Apart from the above literatures, there are also few research works in which MCDM techniques are being used for selecting electronics devices, household appliances or other items that are associated with our daily life, for example, selection of desktop (Mitra and Goswami, 2019a; 2019b) and laptop computers (Adali and Isik, 2017), selection of mobiles (Goswami and Mitra, 2020), car selection (Sri Krishna, et al., 2014), refrigerator selection (Mitra and Kundu, 2017; 2018), and air conditioner selection (Adali and Isik, 2016), that have been recorded but there are very few researchers who have adopted and applied PROMETHEE methods for solving decision-making problems associated with our daily life apart from industrial applications. So, such an initiative is taken in this article to apply an integrated AHP-PROMETHEE (Butowski, 2018; Kilic, et al., 2015; Polat, et al., 2016; Turcksin, et al., 2011; Wang and Yang, 2007) methodologies to solve the laptop selection problems, where AHP is used for calculating the criteria weightages and PROMETHEE is used for the final ranking of the alternatives.

3 Materials and Methods

This section consists of all the step-wise calculation details of AHP and PROMETHEE. The weightages of the criteria are calculated using AHP, and the final ranking of the alternatives are performed using PROMETHEE, which are discussed in Sections 3.1 and 3.2, respectively.

3.1 Analytic Hierarchy Process (AHP)

AHP is an MCDM technique for establishing and analyzing complex decisions based on psychology and mathematics (Saaty, 1980; 2001; 2008; 2010). It was first developed by professor Thomas L. Saaty in 1980 (Saaty, 1980). The AHP methodology is illustrated briefly in Fig. 1.

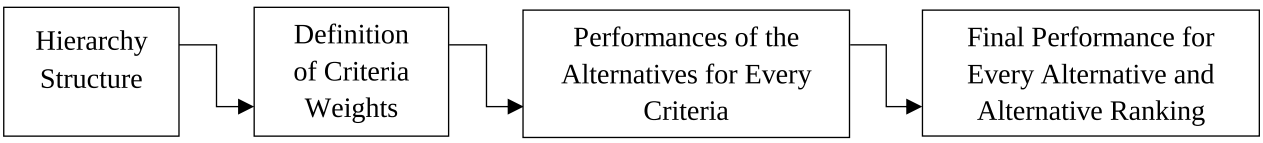

Figure 1. AHP methodology (*Source:* Kolios, et al., 2016)

The steps involved in AHP for calculating the criteria weightages are given as follows:

Step 1: An n × n pair-wise comparison matrix is created based on Saaty's 9 pair comparison scale (Saaty, 1980), which is presented in Table 3.

Table 3. Pair-wise comparison matrix (*Source:* Own elaboration)

Comparisons	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color
Processor	1	5	7	3	2	7	9
Hard disk capacity	1/5	1	3	1/3	1/3	2	5
Operating system	1/7	1/3	1	1/5	1/3	1/3	3
RAM	1/3	3	5	1	2	3	9
Screen size	1/2	3	3	1/2	1	3	7
Brand	1/7	1/2	3	1/3	1/3	1	5
Color	1/9	1/5	1/3	1/9	1/7	1/5	1
Total	**2.43016**	**13.03333**	**22.33333**	**5.47778**	**6.14286**	**16.53333**	**39**

This pair-wise comparison matrix compares all the criteria among each other, and the relative importance of one criterion over other is given according to the Saaty pair-wise comparison scale.

Table 5 presents the Saaty's 9 pair comparison scale. Here, n is the number of criteria considered for the analysis. In this case, seven criteria are considered; hence, n = 7.

Step 2: The pair-wise comparison matrix (presented in Table 3) is normalized by dividing all the elements of Table 3 by their respective column sum. Table 4 presents the normalized pair-wise comparison matrix.

Table 4. Normalized pair-wise comparison matrix (*Source:* Own elaboration)

Comparisons	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color	Priority Vector	Weight %
Processor	0.41150	0.38363	0.31343	0.54767	0.32558	0.42339	0.23077	0.37657	37.657
Hard disk capacity	0.08230	0.07673	0.13433	0.06085	0.05426	0.12097	0.12821	0.09395	9.395
Operating system	0.05879	0.02558	0.04478	0.03651	0.05426	0.02016	0.07692	0.04529	4.529
RAM	0.13717	0.23018	0.22388	0.18256	0.32558	0.18145	0.23077	0.21594	21.594
Screen size	0.20575	0.23018	0.13433	0.09128	0.16279	0.18145	0.17949	0.16932	16.932
Brand	0.05879	0.03836	0.13433	0.06085	0.05426	0.06048	0.12821	0.07647	7.647
Color	0.04572	0.01535	0.01493	0.02028	0.02326	0.01210	0.02564	0.02247	2.247
Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**100**

The normalized values are calculated and presented in Table 4. All the row averages (priority vector) are found out for every criterion, which are the criteria weightages. The criteria weightages are found out to be as follows: $w_{processor}$ = 0.37657 or 37.657%, $w_{hard\ disk\ capacity}$ = 0.09395 or 9.395%, $w_{operating\ system}$ = 0.04529 or 4.529%, w_{RAM} = 0.21594 or 21.594%, $w_{screen\ size}$ = 0.16932 or 16.932%, w_{brand} = 0.07647 or 7.647%, and w_{color} = 0.02247 or 2.247%.

Table 4 presents the normalized decision matrix along with the criteria weightages. Now the next step is to check the consistency whether the decision maker's judgment is true and consistent.

Step 3: Calculate the average consistency (λ_{max}). The priority vector matrix (priority vector column in Table 4) is multiplied with the pair-wise comparison matrix (Table 3) and λ_{max} is calculated as shown in details below:

$$\begin{bmatrix} 1 & 5 & 7 & 3 & 2 & 7 & 9 \\ 1/5 & 1 & 3 & 1/3 & 1/3 & 2 & 5 \\ 1/7 & 1/3 & 1 & 1/5 & 1/3 & 1/3 & 3 \\ 1/3 & 3 & 5 & 1 & 2 & 3 & 9 \\ 1/2 & 3 & 3 & 1/2 & 1 & 3 & 7 \\ 1/7 & 1/2 & 3 & 1/3 & 1/3 & 1 & 5 \\ 1/9 & 1/5 & 1/3 & 1/9 & 1/7 & 1/5 & 1 \end{bmatrix} \times \begin{bmatrix} 0.37657 \\ 0.09395 \\ 0.04529 \\ 0.21594 \\ 0.16932 \\ 0.07647 \\ 0.02247 \end{bmatrix} = \begin{bmatrix} 2.88726 \\ 0.69881 \\ 0.32292 \\ 1.61999 \\ 1.26995 \\ 0.55385 \\ 0.16167 \end{bmatrix}$$

$$\begin{vmatrix} 2.88726/0.37657 \\ 0.69881/0.09395 \\ 0.32292/0.04529 \\ 1.61999/0.21594 \\ 1.26995/0.16932 \\ 0.55385/0.07647 \\ 0.16167/0.02247 \end{vmatrix} = \begin{vmatrix} 7.66733 \\ 7.43821 \\ 7.13075 \\ 7.50203 \\ 7.50018 \\ 7.24284 \\ 7.19579 \end{vmatrix} \left\| \begin{matrix} \text{Processor} \\ \text{Hard disk capacity} \\ \text{Operating system} \\ \text{RAM} \\ \text{Screen size} \\ \text{Brand} \\ \text{Color} \end{matrix} \right.$$

The consistencies of all the seven criteria are found out. Now, calculate the averages of these seven values to find out the average consistency (λ_{max}).

Average consistency

$$(\lambda_{max}) = \frac{7.66733 + 7.43821 + 7.13075 + 7.50203 + 7.50018 + 7.24284 + 7.19579}{7}$$

$= 7.38245$.

Step 4: Calculate the consistency ratio (CR) value and check for consistency. CR value is calculated using Equation 1 as shown below.

$$\text{Consistency ratio (CR)} = \frac{\text{CI}}{\text{RI}} \qquad (1)$$

where CI is the consistency index and RI is the randomly generated CI.

CI is calculated using Equation 2, and RI value can be obtained from Table 6 according to the number criteria. In this case, n = 7, so the RI value corresponding to n = 7 is 1.32.

$$\text{Consistency Index (CI)} = \frac{(\lambda_{max} - n)}{(n-1)} \qquad (2)$$

Here, λ_{max} is the average consistency and n is the number of criteria. In this case, n = 7.

Using Equations 1 and 2, CI and CR values are found to be 0.06374 (CI value) and 0.04829 (CR value) or 4.829%.

Here it can be seen that the CR value is less than 0.1 ($0.04829 < 0.1$), that is, the inconsistency is within 10%; hence, it can be concluded that the decision maker judgment is true and consistent.

Table 5. Saaty's pair-wise comparison scale (*Source*: Saaty, 1980)

Saaty's pair wise comparison scale	Compare factor of i & j
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong or Demonstrated Importance
9	Extreme Importance
2, 4, 6, 8	Intermediate values when compromise is needed

Table 6. Randomly generated consistency index (RI) values (*Source:* Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

3.2 Preference Ranking Organization Method for Enrichment of Evaluations

In early 1980s, for the first time, Brans presented the PROMETHEE outranking method in 1982 at a conference organized by R. Nadeau and M. Landry at the University Laval, Québec, Canada (Brans, 1982). After that, developments have been carried out for more than a decade to bring out various versions of PROMETHEE by Brans along with other researchers (Brans, 1982; Brans, et al., 1984, 1986; Brans and Mareschal, 1992, 1994, 1995; Brans and Vincke, 1985). The PROMETHEE methodology are explained briefly in Fig. 2.

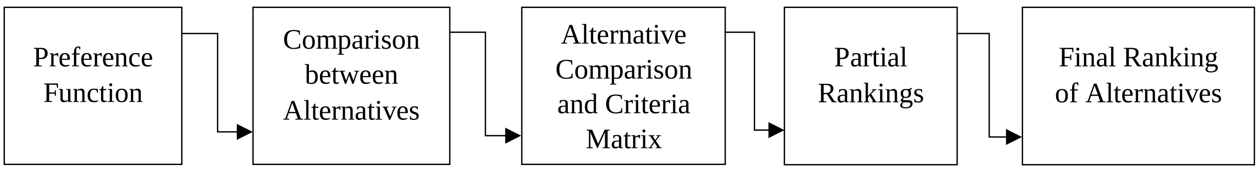

Figure 2. PROMETHEE methodology (*Source:* Kolios, et al., 2016)

The steps involved in PROMETHEE are described as follows.

Step 1: Create an m × n evaluation (decision) matrix according to Equation 3 based on the Hwang and Yoon comparison scale (Hwang and Yoon, 1981), which is presented in Table 8, where m is the number of alternatives and n is the number of criteria. Table 7 presents the decision matrix.

$$X = [x_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (3)$$

where i = 1, 2, 3…., m and j = 1, 2, 3…., n.

Table 7. Evaluation matrix (*Source:* Own elaboration)

Models	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color
Model 1	3	5	3	5	3	9	3
Model 2	5	7	5	5	7	3	3
Model 3	5	9	9	7	7	7	5
Model 4	7	9	9	9	9	2	9
Model 5	5	7	9	7	7	9	9
Model 6	3	5	5	5	7	5	3
Max	7	9	9	9	9	9	9
Min	3	5	3	5	3	2	3

Table 8. Hwang ang Yoon comparison scale (*Source:* Hwang and Yoon, 1981)

Qualitative Estimation	Bad	Good	Average	Very Good	Excellent	Types of Criteria
Quantitative Estimation	1	3	5	7	9	Max
	9	7	5	3	1	Min

Step 2: The decision matrix presented in Table 7 is normalized using Equations 4 and 5 according to the nature of the selected criteria.

For beneficial criteria

$$R_{ij} = \frac{[x_{ij} - \min(x_{ij})]}{[\max(x_{ij}) - \min(x_{ij})]}, \quad (4)$$

For Non-beneficial criteria or cost criteria

$$R_{ij} = \frac{[\max(x_{ij}) - x_{ij}]}{[\max(x_{ij}) - \min(x_{ij})]}, \quad (5)$$

where i = 1, 2, 3…. m; j = 1, 2, 3…. n.

All the criteria considered for this analysis are beneficial in nature, that is, whose higher values are desired. So Equation 4 is used for the normalization of the decision matrix. Table 9 presents the normalized decision matrix.

Table 9. Normalized decision matrix (*Source:* Own elaboration)

Models	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color
Model 1	0	0	0	0	0	1	0
Model 2	0.5	0.5	0.33333	0	0.66667	0.14286	0
Model 3	0.5	1	1	0.5	0.66667	0.71429	0.33333
Model 4	1	1	1	1	1	0	1
Model 5	0.5	0.5	1	0.5	0.66667	1	1
Model 6	0	0	0.33333	0	0.66667	0.42857	0

Step 3: Calculate the evaluative differences of the ith alternative with respect to the other alternatives using Equation 6.

The evaluative differences (deviations) are calculated and presented in Table 10.

$$D\ (Ma - Mb) = (R_{(ij)_a} - R_{(ij)_b}) \quad (6)$$

Table 10. Evaluative difference of ith alternatives with respect other alternatives
(*Source:* Own elaboration)

Evaluative difference	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color
Model 1							
D (M1-M2)	-0.5	-0.5	-0.33333	0	-0.66667	0.85714	0
D (M1-M3)	-0.5	-1	-1	-0.5	-0.66667	0.28571	-0.33333
D (M1-M4)	-1	-1	-1	-1	-1	1	-1
D (M1-M5)	-0.5	-0.5	-1	-0.5	-0.66667	0	-1
D (M1-M6)	0	0	-0.33333	0	-0.66667	0.57143	0
Model 2							
D (M2-M1)	0.5	0.5	0.33333	0	0.66667	-0.85714	0
D (M2-M3)	0	-0.5	-0.66667	-0.5	0	-0.57143	-0.33333
D (M2-M4)	-0.5	-0.5	-0.66667	-1	-0.33333	0.14286	-1
D (M2-M5)	0	0	-0.66667	-0.5	0	-0.85714	-1
D (M2-M6)	0.5	0.5	0	0	0	-0.28571	0
Model 3							
D (M3-M1)	0.5	1	1	0.5	0.66667	-0.28571	0.33333
D (M3-M2)	0	0.5	0.66667	0.5	0	0.57143	0.33333
D (M3-M4)	-0.5	0	0	-0.5	-0.33333	0.71429	-0.66667
D (M3-M5)	0	0.5	0	0	0	-0.28571	-0.66667
D (M3-M6)	0.5	1	0.66667	0.5	0	0.28571	0.33333
Model 4							
D (M4-M1)	1	1	1	1	1	-1	1
D (M4-M2)	0.5	0.5	0.66667	1	0.33333	-0.14286	1
D (M4-M3)	0.5	0	0	0.5	0.33333	-0.71429	0.66667
D (M4-M5)	0.5	0.5	0	0.5	0.33333	-1	0
D (M4-M6)	1	1	0.66667	1	0.33333	-0.42857	1
Model 5							
D (M5-M1)	0.5	0.5	1	0.5	0.66667	0	1
D (M5-M2)	0	0	0.66667	0.5	0	0.85714	1
D (M5-M3)	0	-0.5	0	0	0	0.28571	0.66667
D (M5-M4)	-0.5	-0.5	0	-0.5	-0.33333	1	0
D (M5-M6)	0.5	0.5	0.66667	0.5	0	0.57143	1
Model 6							
D (M6-M1)	0	0	0.33333	0	0.66667	-0.57143	0
D (M6-M2)	-0.5	-0.5	0	0	0	0.28571	0
D (M6-M3)	-0.5	-1	-0.66667	-0.5	0	-0.28571	-0.33333
D (M6-M4)	-1	-1	-0.66667	-1	-0.33333	0.42857	-1
D (M6-M5)	-0.5	-0.5	-0.66667	-0.5	0	-0.57143	-1

Step 4: Calculate the preference function P_j (Ma, Mb).

The preference function is calculated using the following two conditions given by Equations 7 and 8.

$$P_j\ (Ma, Mb) = 0 \quad (7)$$

$$\text{if } R_{(ij)_a} \leq R_{(ij)_b} \rightarrow D\ (Ma - Mb) \leq 0$$

$$P_j\ (Ma, Mb) = (R_{(ij)_a} - R_{(ij)_b}) \quad (8)$$

$$\text{if } R_{(ij)_a} > R_{(ij)_b} \rightarrow D\ (Ma - Mb) > 0$$

Table 11. Preference function, P_j (Ma, Mb)
(*Source:* Own elaboration)

Weights (w_j)	0.37657	0.09395	0.04529	0.21594	0.16932	0.07647	0.02247
Evaluative difference	Processor	Hard disk capacity	Operating system	RAM	Screen size	Brand	Color
Model 1							
P (M1, M2)	0	0	0	0	0	0.85714	0
P (M1, M3)	0	0	0	0	0	0.28571	0
P (M1, M4)	0	0	0	0	0	1	0
P (M1, M5)	0	0	0	0	0	0	0
P (M1, M6)	0	0	0	0	0	0.57143	0
Model 2							
P (M2, M1)	0.5	0.5	0.33333	0	0.66667	0	0
P (M2, M3)	0	0	0	0	0	0	0
P (M2, M4)	0	0	0	0	0	0.14286	0
P (M2, M5)	0	0	0	0	0	0	0
P (M2, M6)	0.5	0.5	0	0	0	0	0
Model 3							
P (M3, M1)	0.5	1	1	0.5	0.66667	0	0.33333
P (M3, M2)	0	0.5	0.66667	0.5	0	0.57143	0.33333
P (M3, M4)	0	0	0	0	0	0.71429	0
P (M3, M5)	0	0.5	0	0	0	0	0
P (M3, M6)	0.5	1	0.66667	0.5	0	0.28571	0.33333
Model 4							
P (M4, M1)	1	1	1	1	1	0	1
P (M4, M2)	0.5	0.5	0.66667	1	0.33333	0	1
P (M4, M3)	0.5	0	0	0.5	0.33333	0	0.66667
P (M4, M5)	0.5	0.5	0	0.5	0.33333	0	0
P (M4, M6)	1	1	0.66667	1	0.33333	0	1
Model 5							
P (M5, M1)	0.5	0.5	1	0.5	0.66667	0	1
P (M5, M2)	0	0	0.66667	0.5	0	0.85714	1
P (M5, M3)	0	0	0	0	0	0.28571	0.66667
P (M5, M4)	0	0	0	0	0	1	0
P (M5, M6)	0.5	0.5	0.66667	0.5	0	0.57143	1
Model 6							
P (M6, M1)	0	0	0.33333	0	0.66667	0	0
P (M6, M2)	0	0	0	0	0	0.28571	0
P (M6, M3)	0	0	0	0	0	0	0
P (M6, M4)	0	0	0	0	0	0.42857	0
P (M6, M5)	0	0	0	0	0	0	0

From Equations 7 and 8, it is clear that if the difference, that is, D (Ma − Mb) in Table 10 is less than or equal to zero, then substitute the preference function value as zero and if D (Ma - Mb) value is greater than zero, then the differences, that is, ($R_{(ij)_a} - R_{(ij)_b}$) is used as the preference function value.

In more easy words, if the value in any of the cell in Table 10 is less than or equal to zero (i.e., negative values), then substitute the value as zero and if the value in any of the cell in Table 10 is greater than zero, then leave it untouched. So, by substituting all the negative values of Table 10 by zeroes and keeping all the positive values as it is, thus obtaining the Table 11 as shown above.

Step 5: Calculate the aggregated preference, π (Ma, Mb) using Equation 9 as shown below.

$$\pi\ (\text{Ma, Mb}) = \frac{\left[\sum_{j=1}^{n} w_j P_j\ (\text{Ma,Mb})\right]}{\sum_{j=1}^{n} w_j}. \qquad (9)$$

The summation of the criteria weightages is always equal to 1; hence, the denominator of Equation 9 becomes one. Now, multiplying all the criteria weightages with their respective column elements of Table 11 and using Equation 9, find all aggregated preference values π (Ma, Mb).

Table 12 presents the calculated aggregated preference values.

Table 12. Calculating the aggregated preference, π (Ma, Mb)
(*Source:* Own elaboration)

Weights	0.37657	0.09395	0.04529	0.21594	0.16932	0.07647	0.02247	1
								Aggregated preference, π (Ma, Mb)
Model 1								
π (M1, M2)	0	0	0	0	0	0.06554	0	0.06554
π (M1, M3)	0	0	0	0	0	0.02185	0	0.02185
π (M1, M4)	0	0	0	0	0	0.07647	0	0.07647
π (M1, M5)	0	0	0	0	0	0	0	0
π (M1, M6)	0	0	0	0	0	0.04370	0	0.04370
Model 2								
π (M2, M1)	0.18828	0.04697	0.01510	0	0.11288	0	0	0.36323
π (M2, M3)	0	0	0	0	0	0	0	0
π (M2, M4)	0	0	0	0	0	0.01092	0	0.01092
π (M2, M5)	0	0	0	0	0	0	0	0
π (M2, M6)	0.18828	0.04697	0	0	0	0	0	0.23526
Model 3								
π (M3, M1)	0.18828	0.09395	0.04529	0.10797	0.11288	0	0.00749	0.55586
π (M3, M2)	0	0.04697	0.03019	0.10797	0	0.04370	0.00749	0.23632
π (M3, M4)	0	0	0	0	0	0.05462	0	0.05462
π (M3, M5)	0	0.04697	0	0	0	0	0	0.04697
π (M3, M6)	0.18828	0.09395	0.03019	0.10797	0	0.02185	0.00749	0.44973
Model 4								
π (M4, M1)	0.37657	0.09395	0.04529	0.21594	0.16932	0	0.02247	0.92353
π (M4, M2)	0.18828	0.04697	0.03019	0.21594	0.05644	0	0.02247	0.56030
π (M4, M3)	0.18828	0	0	0.10797	0.05644	0	0.01498	0.36767
π (M4, M5)	0.18828	0.04697	0	0.10797	0.05644	0	0	0.39967
π (M4, M6)	0.37657	0.09395	0.03019	0.21594	0.05644	0	0.02247	0.79555

Table 12. Calculating the aggregated preference, π (Ma, Mb), cont.
(*Source:* Own elaboration)

Weights	0.37657	0.09395	0.04529	0.21594	0.16932	0.07647	0.02247	1
								Aggregated preference, π (Ma, Mb)
Model 5								
π (M5, M1)	0.18828	0.04697	0.04529	0.10797	0.11288	0	0.02247	0.52386
π (M5, M2)	0	0	0.03019	0.10797	0.00000	0.06554	0.02247	0.22617
π (M5, M3)	0	0	0	0	0	0.02185	0.01498	0.03683
π (M5, M4)	0	0	0	0	0	0.07647	0	0.07647
π (M5, M6)	0.18828	0.04697	0.03019	0.10797	0	0.04370	0.02247	0.43958
Model 6								
π (M6, M1)	0	0	0.01510	0	0.11288	0	0	0.12798
π (M6, M2)	0	0	0	0	0	0.02185	0	0.02185
π (M6, M3)	0	0	0	0	0	0	0	0
π (M6, M4)	0	0	0	0	0	0.03277	0	0.03277
π (M6, M5)	0	0	0	0	0	0	0	0

Step 6: Create an aggregate preference function matrix. Depending on the number of alternatives *m*, $m \times m$ matrix is formed. In this present analysis, 6 alternatives are considered so 6×6 matrix is formed as shown in Table 13.

Table 13. Aggregate preference function matrix (*Source:* Own elaboration)

Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model 1	-	0.06554	0.02185	0.07647	0	0.04370
Model 2	0.36323	-	0	0.01092	0	0.23526
Model 3	0.55586	0.23632	-	0.05462	0.04697	0.44973
Model 4	0.92353	0.56030	0.36767	-	0.39967	0.79555
Model 5	0.52386	0.22617	0.03683	0.07647	-	0.43958
Model 6	0.12798	0.02185	0	0.03277	0	-

For π (M1, M2), the aggregated preference value is 0.06554; this means the aggregated preference value of Model 1 with respect to Model 2 is 0.06554 (from Table 12). So this value (i.e., 0.06554) is allotted in the cell 1, 2 as shown in Table 13.

Similarly, for π (M1, M3), the aggregated preference value of Model 1 with respect to Model 3 is 0.02185 (from Table 12), so this value (i.e., 0.02185) is allotted in the cell 1, 3 as shown in Table 13.

In this way, the aggregated preference function value from Table 12 is allotted in all the cells of the above matrix, thus forming Table 13. When an alternative is compared to itself, no values should be assigned.

Step 7: Determination of the leaving and entering outranking flow of the alternatives.

The leaving and entering outranking flow in case of PROMETHEE I is calculated and presented in Table 14 using Equations 10 and 11 given below.

Leaving (positive) flow for a_{th} alternative, φ^+,

$$\sum_{b=1}^{m} \pi\,(a, b) \tag{10}$$

Entering (negative) flow for a_{th} alternative, φ^-,

$$\sum_{b=1}^{m} \pi\,(a, b) \tag{11}$$

for example, $a \neq b$.

The leaving and entering outranking flow in case of PROMETHEE II is calculated and presented in Table 15 using the Equations 12 and 13 given below.

Leaving (positive) flow for a_{th} alternative, φ^+,

$$\frac{1}{n-1}\sum_{b=1}^{m}\pi\,(a,b) \tag{12}$$

Entering (negative) flow for a_{th} alternative, φ^-,

$$\frac{1}{n-1}\sum_{b=1}^{m}\pi\,(a,b) \tag{13}$$

for example, $a \neq b$ and n is the number of alternatives.

Table 14. Determination of leaving and entering outranking flow (PROMETHEE I) (*Source:* Own elaboration)

Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Leaving flow φ+
Model 1	-	0.06554	0.02185	0.07647	0	0.04370	0.20756
Model 2	0.36323	-	0	0.01092	0	0.23526	0.60942
Model 3	0.55586	0.23632	-	0.05462	0.04697	0.44973	1.34350
Model 4	0.92353	0.56030	0.36767	-	0.39967	0.79555	3.04672
Model 5	0.52386	0.22617	0.03683	0.07647	-	0.43958	1.30291
Model 6	0.12798	0.02185	0	0.03277	0	-	0.18260
Entering flow φ-	2.49446	1.11018	0.42635	0.25125	0.44664	1.96382	

Table 15. Determination of leaving and entering outranking flow (PROMETHEE II) (*Source:* Own elaboration)

Models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Leaving flow φ+
Model 1	-	0.06554	0.02185	0.07647	0.00000	0.04370	0.04151
Model 2	0.36323	-	0.00000	0.01092	0.00000	0.23526	0.12188
Model 3	0.55586	0.23632	-	0.05462	0.04697	0.44973	0.26870
Model 4	0.92353	0.56030	0.36767	-	0.39967	0.79555	0.60934
Model 5	0.52386	0.22617	0.03683	0.07647	-	0.43958	0.26058
Model 6	0.12798	0.02185	0.00000	0.03277	0.00000	-	0.03652
Entering flow φ-	0.49889	0.22204	0.08527	0.05025	0.08933	0.39276	

Step 8: Calculate the net outranking flow of each alternative using Equation 14. The net outranking flow of the alternatives are determined only in case of PROMETHEE II for the complete ranking of the alternatives. The net outranking flow of the alternatives is presented Table 16.

$$\text{Net Flow } \{\varphi(a)\} = \text{Leaving Flow } \{\varphi^+(a)\} - \text{Entering Flow } \{\varphi^-(a)\} \tag{14}$$

Table 16. Net outranking flow of the alternatives (*Source:* Own elaboration)

Models	Leaving flow φ+	Entering flow φ-	Net flow φ
Model 1	0.04151	0.49889	-0.45738
Model 2	0.12188	0.22204	-0.10015
Model 3	0.26870	0.08527	0.18343
Model 4	0.60934	0.05025	0.55909
Model 5	0.26058	0.08933	0.17125
Model 6	0.03652	0.39276	-0.35624

4 Results and Discussions

The best alternatives chosen by PROMETHEE method depends on the leaving and entering outranking flows of each alternatives, which are calculated in Section 3 and presented in Table 14 for PROMETHEE I and in Table 15 for PROMETHEE II.

In case of PROMETHEE II, the net outranking flow is also calculated as shown in Table 16.

As mentioned earlier, PROMETHEE 1 provides the partial ranking and PROMETHEE II provides the complete ranking of the alternatives. The outcome results from both the methods are explained in Sections 4.1 and 4.2, respectively.

4.1 Outcome Results from PROMETHEE I

In case of PROMETHEE I, partial ranking is performed and the decision made by the decision maker is based on the three conditions given below.

In PROMETHEE I, instead of defining the rank, preferences are calculated.

Condition 1: Alternative a is preferred to/outranks alternative b, aPb

aPb if:

$\varphi^+ (a) > \varphi^+ (b)$ and $\varphi^- (a) < \varphi^- (b)$; or

$\varphi^+ (a) > \varphi^+ (b)$ and $\varphi^- (a) = \varphi^- (b)$; or

$\varphi^+ (a) = \varphi^+ (b)$ and $\varphi^- (a) < \varphi^- (b)$

Condition 2: Indifference situation, aIb

aIb if:

$\varphi^+ (a) = \varphi^+ (b)$ and $\varphi^- (a) = \varphi^- (b)$

Condition 3: Incomparable situation, aRb

aRb if:

$\varphi^+ (a) > \varphi^+ (b)$ and $\varphi^- (a) > \varphi^- (b)$; or

$\varphi^+ (a) < \varphi^+ (b)$ and $\varphi^- (a) < \varphi^- (b)$

On the basis of the above three conditions, all the alternatives are compared among each other and the decisions are made comparing one laptop model over another, which is presented in Table 17.

As there are 6 alternatives selected for this research purposes, there will be 15 comparisons in total. Table 17 presents the choices and preferences of one model over another.

Table 17. Comparisons of the laptop models among each other (*Source:* Own elaboration)

Sl. No.	Comparisons	Sl. No.	Comparisons
1	Model 2 P Model 1	9	Model 2 P Model 6
2	Model 3 P Model 1	10	Model 4 P Model 3
3	Model 4 P Model 1	11	Model 3 P Model 5
4	Model 5 P Model 1	12	Model 3 P Model 6
5	Model 1 R Model 6	13	Model 4 P Model 5
6	Model 3 P Model 2	14	Model 4 P Model 6
7	Model 4 P Model 2	15	Model 5 P Model 6
8	Model 5 P Model 2		

4.2 Outcome Results from PROMETHEE II

Ranking is performed according to the decreasing order of net flow values. Table 18 shows the complete ranking of the laptop models. The preference ranking order of the models are given as follows:

Model 4 > Model 3 > Model 5 >
Model 2 > Model 6 > Model 1

Table 18. Ranking of the laptop models (*Source:* Own elaboration)

Models	Net flow φ	Ranking
Model 1	-0.45738	Rank 6
Model 2	-0.10015	Rank 4
Model 3	0.18343	Rank 2
Model 4	0.55909	Rank 1
Model 5	0.17125	Rank 3
Model 6	-0.35624	Rank 5

5 Conclusions

At the end of this analysis, it can be concluded that Model 4 is the best laptop model among these six available models followed by Model 3 and Model 5. Model 4 is coming out with the highest net flow value, that is, 0.55909, which enables it to occupy the rank 1 position, and similarly, Model 1 is coming out with the lowest net flow value, that is, −0.45738, so it occupies the last position, which denotes that it is the worst model among these group.

Although seven main important criteria are considered for this analysis, there are other specifications, both technical and nontechnical, that can also be included along with these, for example, display resolution, service center, weight, customer support, and graphics card for making these decision-making problem more precise and accurate. However, the same problem can also be carried out by applying other MCDM methods and the results can be compared with these results.

6 References

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