Universiti Teknologi MARA
Cawangan Perlis
Jurnal Intelek

Volume 14 Issue 2 (December 2019)

Evaluate and Rank the Smartphone Brand Using Fuzzy AHP and PROMETHEE

Diana Sirmayunie Mohd Nasir[1*], Nurshahira Zawawi[2], Suzanawati Abu Hasan[3]
[1,2,3] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, 02600 Arau, Perlis, Malaysia

*Authors' Email Address:*dianasirmayunie@uitm.edu.my, suzan540@perlis uitm.edu.my*
Received Date: 22 August 2019
Accepted Date: 31 October 2019

ABSTRACT

A buying decision process is one of the Multi-Criteria Decision Making (MCDM) problems faced by everyone in daily life. One example is the selection of smartphones brand in the market. Thus, the study is conducted to evaluate the most effective criteria for buying smartphones and to rank the people's preferences on smartphone based on its brand. Six criteria (price, operating system, memory, display, camera and battery) and three alternatives which are the smartphone brands (Oppo, Samsung and Apple) were chosen in the study. Two main processes were involved, which are: 1) evaluate the smartphone criteria using Fuzzy Analytic Hierarchy Process (AHP) and 2) ranking the brand using Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). Surveys and questionnaires were conducted and evaluated by decision makers who are the smartphone's users. Results showed storage memory is considered as prominent criteria in choosing a smartphone meanwhile the consumers firstly prefer Oppo, secondly Apple and thirdly Samsung. Future work in this study may use other alternatives to be ranked by considering other top models as well.

Keywords: *Multiple criteria decision making, smartphone brand, Fuzzy AHP, Fuzzy PROMETHEE*

INTRODUCTION

Mobile phone, also known as the cell phone has become worldwide in communication industry. A cell phone is defined as a communication device that can make a call, receive a call and send a message via Short Message Service (SMS) (Ware, 2018). As time evolved, smartphones have replaced the old cell phones (Fendelman, 2017). The first feature in smartphones is, the memory capacity. Today, smartphones have offered wide capacity to store pictures, videos, and applications in Micro SD cards compared to old mobile phones. Second is the Internet connection. Users can access the Internet using mobile plans through a web browser. Next, the camera phones plummet the market in the early 00's. These devices are used in numerous spots throughout countries and becoming an important tool in everyday lives (Lessler, 2017).

Therefore, it becomes one of the essential devices that everyone must have. Year by year, the technology of smartphone has growth swiftly (Manjoo, 2014). The features keep boosting in the smartphone in order to satisfy the demand. Nonetheless, people or consumers are facing the purchase decision problem of choosing a smartphone since there are a lot of brands and features of smartphone in the market. Rahim et al. (2016) said that users especially youths have a problem in term of motives and choices in the

ISSN: 2231-7716
DOI: http://10.24191/ji.v14i2.216

smartphone buying decision process due to the evolution of the smartphone industry that goes rapidly. Khan, Kulkarni and Bharathi (2014) stated that the brand itself plays a major role in shaping an image of the products in the minds of consumers. In this context, multi-criteria decision analysis technique can be used as a decision-making tool. Consequently, the purpose of this study is to use Fuzzy AHP to evaluate the criteria of a smartphone and to rank the brand of smartphones (Oppo, Samsung and Apple) using PROMETHEE.

LITERATURE REVIEW

This section can be discussed in two different sections. First section focuses on methodology related to literature and the second section provides discussion on the main topic of this study.

The Methodology Related Literature

Since this study used Fuzzy AHP and PROMETHEE as method, this section of literature will focus on the paper conducted with the same method. Alp et al. (2011) was proposed to solve selection problem of bus garage location in Istanbul. The main objective was to minimize the distance traveled. The six criteria which were cost, infrastructure, accessibility, social and economic structure, macro factors and environmental factors were used as input to rank the alternatives by using Fuzzy AHP. Meanwhile, the locations considered were Beylikdüzü, Arnavutköy and Silivri. These alternatives were evaluated using PROMETHEE. As the result, Silivri was the most ranked location and accessibility was the most important criteria.

Next, Çetinkaya et al. (2017) introduced a hybric fuzzy AHP and PROMETHEE for 3D printer selection in production business sector. There were three levels involved. First, the main criteria were evaluated such as economic, performance, environmental and technical with its sub-criteria using Fuzzy AHP. Five 3D printers were considered namely Ultimaker2, Zortrax M200, Ultimaker Original+, Flashforge Creator and Up+2. From the results, only one sub-criteria and two sub-criteria were chosen as the most important sub-criteria in both performance and technical. PROMETHEE was used to rank the alternatives and both Ultimaker2 and Ultimaker Original+ were considered as the best 3D printers.

Meanwhile, EI Mokrini et al. (2016) proposed a study in the evaluation of outsourcing risks in the pharmaceutical supply chain using fuzzy AHP and PROMETHEE approach in the pharmaceutical industry. The purpose was to rank the risk according to different criteria. There were 16 risks in outsourcing logistics considered namely R1 until R16 under each section. Examples of the risks were poor infrastructure, delivery delay and others. Altogether, there were six criteria taken into consideration. As a result, impact on patients' safety criteria was measured as a high priority compared to others and R1 and R6 risk types were chosen with levels of very high risk.

The previous studies are related to this paper with similar methodology was mentioned above, now we will focus on the previous studies with topics that are related to our paper.

Topic related literature

Since our topic is the selection of smartphone, therefore this section will discuss on the same related topic.

A study from Khan et al. (2014) used an image-based survey method on studying buying decision of mobile phone. Three criteria were considered, which were price, brand and brand ambassador. A survey with picture representations is conducted for the collection of data. Paired samples t-test and ANOVA test were used for data analysis. The results showed that brand and brand ambassador were the prominent criteria among the three criteria considered that affected the purchasing behavior of customers.

Meanwhile, Shrestha (2016) highlighted that majority of respondents said it was better to have a smartphone with the better features compared to price competitively among similar model of smartphone brands. The features of the smartphone have been ranked by using deductive reasoning with battery life in a first place followed by Internet connection, touch screen, camera quality and resolution.

Next, Belbag et al. (2016) has proposed a study on evaluation on choosing smartphone brands using fuzzy ELECTRE I method. The purpose of this study was to choose the most effective criteria by measuring the evaluation of consumers on buying smartphones. Five brands were chosen which are Samsung, Apple, LG, HTC and Sony. There were seven criteria taken into consideration. As a result, it is shown that Samsung was the top preferred brand among others as smartphone features affected the brands directly.

It was found that there is no study in literature that uses Fuzzy AHP and PROMETHEE for choosing a smartphone brand. Thus, this study was aimed to apply both Fuzzy AHP and PROMETHEE method to evaluate smartphone criteria and to rank the smartphone brand.

METHODOLOGY

The proposed methodology consists of three main processes as follows:

Process 1: Determination of Criteria and Smartphone Brands

Firstly, the decision-making team, who was working at smartphone store was selected. The decision makers were asked to evaluate the criteria and rate the smartphone brands. All six criteria are determined from the literature and expert's opinion. Meanwhile, these three brands which are Oppo, Samsung and Apple have been chosen from the marketing article with the title, "The top smartphone brands in the world in 2017" (Basin, 2018). The data was collected through surveys and questionnaires.

Process 2: Evaluate Smartphone Criteria using Fuzzy AHP

The fuzzy AHP method has several steps which are explained by Çebi and Karal (2017) and Chang and Yang (2011) using Chang (1996) extent analysis in applying the comparison of fuzzy numbers principle. The steps of proposed methodology in this paper were discussed here. In this process, the decision makers were asked to evaluate the pairwise comparison of the criteria based on linguistic terms. Later, the criteria will be converted into fuzzy number. A triangular fuzzy number (TFN) M with R can be denoted by $M = (p, q, r)$ such that $\mu_M(x): R \rightarrow [0,1]$.

$$\mu_M = \begin{cases} (x - p)/(q - p), & p \le x \le q \\ (x - r)/(q - r), & q \le x \le r \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where p is the minimum value, q is most possible value and r maximum value.

The decision makers were asked to make pairwise comparison of the smartphone criteria through questionnaire. They were asked to evaluate using linguistic term as shown in table 1 below.

Table 1: The Linguistic Terms for Triangular Fuzzy Number of Degree of Importance

Linguistic terms	Explanation	Triangular Fuzzy Number (TFN)
Equally Important (EQI)	Both criteria are equally important	(1,1,1)
Moderately Important (MI)	One criteria is moderately important than other criteria	(0.5,1.25,2)
Strongly Important (SI)	One criteria is strongly more important than other criteria	(1.5,2.25,3)
Very Strongly Important (VSI)	One criteria is very strongly more important than other criteria	(2.5,3.25,4)
Extremely Important (EI)	One criteria is extremely more important than other criteria	(3.5,4.25,5)

The questionnaire later will be converted into pairwise comparison matrix in the form of 6 x 6 matrix according to its criteria as shown in Table 2, by the first decision maker as example on how it works.

Table 2: Pairwise Comparison Matrix in Linguistic Term of Decision Maker 1

	Price	Operating System	Memory	Display	Camera	Battery
Price		EQI	1/VSI	VSI	1/SI	1/VSI
Operating System			1/MI	VSI	VSI	EQI
Memory				EI	EI	EI
Display					1/MI	1/VSI
Camera						1/VSI
Battery						

The $a_{(\text{Price, Memory})} = \frac{1}{\text{VSI}}$ indicates the reciprocal of linguistic term.

Then, the Fuzzy Comparison Matrix (FCM) of *n* criteria are constructed as Eq.2 below.

$$FCM = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (2)$$

Next, the FCM of decision makers were aggregated using arithmetic mean as shown below:

$$\text{AM} = \left(\min \, \text{p}_{\text{ij}}, \frac{1}{\text{k}} \sum_{\text{k}=1}^{\text{k}} \text{q}_{\text{ij}}, \max \, \text{p}_{\text{ij}} \right) \quad (3)$$

where *k* is the total number of decision maker. Next step, the consistency of matrices is checked to ensure that the judgement of decision makers is consistent. Therefore, the consistency index (CI) is calculated as ratio of the consistency ratio (CR) and random index (RI) which are calculated according to Eq.4 and Eq.5 respectively.

$$\text{CI} = \left(\frac{\lambda_{\text{max}} - \text{n}}{\text{n} - 1} \right) \quad (4)$$

$$CR = \left(\frac{CI}{RI(n)} \right) \quad (5)$$

Then, the value of fuzzy synthetic extent with respect to the criterion from goals is defined as

$$U_k = \sum_{t=1}^{m} M_{gk}^{l} \times \left[\sum_{k=1}^{n} \sum_{l=1}^{m} M_{gk}^{l} \right]^{-1} \quad (6)$$

Where $\sum_{t=1}^{m} M_{gk}^{l} = \left(\sum_{i=1}^{m} p_i, \sum_{i=1}^{m} q_i, \sum_{i=1}^{m} r_i \right)$ and $\left[\sum_{k=1}^{n} \sum_{l=1}^{m} M_{gk}^{l} \right]^{-1} = \left(\frac{1}{\sum_{k=1}^{n} r_k}, \frac{1}{\sum_{k=1}^{n} q_k}, \frac{1}{\sum_{k=1}^{n} p_k} \right)$

Next, the vector weight W_i can be calculated by $W' = \left(f'(Z_1), f'(Z_2), \dots, f'(Z_n) \right)^T$. After normalization, the crisp values for fuzzy weights are calculated by $W = \left(f(Z_1), f(Z_2), \dots, f(Z_n) \right)^T$

Process 3: Rank Smartphone Brand using PROMETHEE

The PROMETHEE method has several steps which were developed by Brans and Vicke (1985). The mathematically calculation steps of PROMETHEE in this study are summarize as follows. First, the alternatives were determined. There were three alternatives of smartphone brands used in this study namely Oppo F9, Samsung Galaxy Note 9 and Apple X. Next, the decision makers were asked to rate smartphone brands based on the rating scale given in the questionnaire using linguistic term as shown in Table 3 below.

Table 3: The Linguistic Variable for Degree of Rating Using Five-Point Likert Scale

Scale	Degree of rating
1	Very Unsatisfied (VU)
2	Unsatisfied (U)
3	Neutral/OK(N)
4	Satisfied (S)
5	Very Satisfied (VS)

Let M be the alternatives set of $A = \{a_1, a_2, \dots, a_m\}$ and n be the criteria set of $B = \{b_1, b_2, \dots, b_n\}$ where $\widetilde{D}$ represents value of alternative m_i and n_j. After that, the deviation of pairwise comparison which is $d_i(x, y) = f_i(x) - f_i(y)$ is determined. Next, the preference function is calculated as follows:

$$P_j(x, y) = 0 \text{ if } N_{(i,j)}(x) \leq N_{(i,j)}(y)$$
$$P_j(x, y) = \left(N_{ij}(x) - N_{ij}(y) \right) \text{ if } N_{ij}(x) > N_{ij}(y) \quad (7)$$

Then, the aggregated preference function $\mu(x, y)$ are calculated for each alternative pair using the preference functions obtained in the previous step. The next step is calculating the preference index $\pi(x, y)$ using Eq. 8 which W_j is the weights that was obtained from the fuzzy AHP evaluations.

$$\mu(x, y) = \frac{\sum_{j=1}^{n} w_j P_j(x, y)}{\sum_{j=1}^{n} w_j} \quad (8)$$

After that, the PROMETHEE I was determined by comparing the leaving flow and entering flow. Sum of $\pi(x, y)$ is used to measure the strength of the alternative (m) and is called as leaving flow (positive outranking) as given in Eq. 9. The next measure is entering flow (negative outranking) as given in Eq.10.

$$\phi^{+}(a) = \frac{1}{m-1}\sum_{d=1}^{m}\pi(x, y) \qquad x \neq y \tag{9}$$

$$\phi^{-}(a) = \frac{1}{m-1}\sum_{d=1}^{m}\pi(x, y) \qquad y \neq x \tag{10}$$

Lastly, the full ranking was determined by PROMETHEE II as shown below:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \tag{11}$$

RESULT AND DISCUSSIONS

After determining the weight of all criteria by Fuzzy AHP, the next process was applying the PROMETHEE method to rank the smartphone brands. Table 4 shows the weight of criteria.

Table 4: Weight of criteria

Criteria	Weight	Rank
Price	0.1327	5
Operating System	0.2005	3
Memory	0.2310	1
Display	0.0894	6
Camera	0.1420	4
Battery	0.2044	2

After step 1 and step 2 have been done as mentioned in process 2 above, the deviation between two alternatives of different criteria were calculated. The result was shown in Table 5.

Table 5: Deviation of aggregated normalize decision matrix

	Price	Operating System	Memory	Display	Camera	Battery
A1A2	0.45	0	0	0	0.1	-0.1
A1A3	0.5	-0.1	-0.05	-0.1	0.05	0.05
A2A1	-0.45	0	0	0	-0.1	0.1
A2A3	0.05	-0.1	-0.05	-0.1	-0.05	0.15
A3A1	-0.5	0.1	0.05	0.1	-0.05	-0.05
A3A2	-0.05	0.1	0.05	0.1	0.05	-0.15

Note: $A1$ =Oppo, $A2$ =Samsung and $A3$ =Apple

Table 6, Table 7, Table 8 show the output that was obtained from Eqns.(7) –(10) as follows:

Table 6: Preference Function of Aggregated Normalize Decision Matrix

	Price	Operating System	Memory	Display	Camera	Battery
A1A2	0.45	0	0	0	0.1	0
A1A3	0.5	0	0	0	0.05	0.05
A2A1	0	0	0	0	0	0.1

A2A3	0.05	0	0	0	0	0.15
A3A1	0	0.1	0.05	0.1	0	0
A3A2	0	0.1	0.05	0.1	0.05	0

Table 7: Aggregated Preference Function of Aggregated Normalize Decision Matrix

	Oppo (A1)	Samsung (A2)	Apple (A3)
Oppo (A1)		0.074	0.0837
Samsung (A2)	0.0205		0.0373
Apple (A3)	0.0405	0.0476	

Table 8: Partial ranking of PROMETHEE I

	Leaving flow	Entering flow
Oppo (A1)	0.0788	0.0305
Samsung (A2)	0.0289	0.0608
Apple (A3)	0.0441	0.0605

Lastly, by PROMETHEE II, the results can be evaluated and the ranking of smartphone brands was determined as shown in Table 9.

Table 9: Full Ranking of alternative

Alternative	Net Outranking Flow	Rank
Oppo	0.0483	1
Samsung	-0.0319	3
Apple	-0.0164	2

CONCLUSION

Choosing a smartphone is one of the Multi-Criteria Decision Making (MCDM) problems as people's decision differs from one another. It involved the consumers' behavior in buying decision. Thus, it can be challenging to some people as there are dozens of smartphone models and brands available in the market. There are two stages involved in this study. The first stage of evaluation criteria is done by Fuzzy AHP. From the results, storage memory gives higher weightage compared to others which indicates the most prominent criteria. This is followed by battery, operating systems, camera, price and display. Therefore, it can be concluded that the price does not necessarily influence the buying decision as people are willing to buy a smartphone at a higher price as long as it satisfies the people's needs.

For the second stage, the smartphone brands are ranked using the PROMETHEE method by taking the criteria input from the first stage. The three brands are Samsung, Apple and Oppo, which can be considered as the most preferred brands. The result shows that Oppo is outranking the others since it gives higher net outranking value compared to other alternatives. To sum up, nowadays, mobile phone is one of the needed devices for communication, but it is not enough to only have basic cell phones. Therefore, the existence of smartphones with a variety of applications and technology make our life easier.

REFERENCES

Alp, Ö. N., Demirtaş, N., Baraçli, H. & Tuzkaya, U. R. (2011, September). Fuzzy AHP PROMETHEE Methodology to Select Bus garage Location: A Case Study for a Firm in the Urban Passenger Transport Sector in Istanbul**.** In Expert Conference "Trends in development of Machinery and Associated Technology", TMT.

Bhasin, H. (2018, January 14). Top 10 Smartphone brands in The World in 2017. Retrieved from https://bit.ly/2hesbKb

Belbag, S., Gungordu, A., Yumusak, T., & Yilmaz, K. G. (2016). The Evaluation of Smartphone brands Choice: An Application with The Fuzzy ELECTRE I Method. International Journal of Business and management Invention, 5(3), pp 55-63.

Brans, J. P., & Vincke, P. (1985). Note A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision Making). Management science, 31(6), 647-656.

Çebi, A., & Karal, H. (2017). An Application of Fuzzy Analytic Hierarchy Process (FAHP) for Evaluating Students' Project. Educational Research and Reviews, 12(3), 120-132.

Çetinkaya, C., Kabak, M., & Özceylan, E. (2017). 3D Printer Selection by Using Fuzzy Analytic Hierarchy Process and PROMETHEE. Bilişim Teknolojileri Dergisi, 10(4), 371-380.

Chang, D. Y. (1996). Applications of The Extent Analysis Method on Fuzzy AHP. European Journal of Operational Research, 95(3), 649-655.

El Mokrini, A., Kafa, N., Dafaoui, E., El Mhamedi, A., & Berrado, A. (2016). Evaluating outsourcing risks in the pharmaceutical supply chain: Case of a multi criteria combined fuzzy AHP-PROMETHEE approach. IFAC PapersOnLine, 49(28), 114-119.

Fendelman, A. (2017, August 15). How Are Cell Phones Different from Smartphones? Retrieved from https://bit.ly/2Hdrpc8

Khan, M., Kulkarni, A., & Bharathi, V. (2014). A Study on Mobile Phone Buying Behavior Using an Image-based Survey. Procedia Economics and Finance, 11, 609-619.

Lessler, A. (2017, May 17). The Mobile Phones of Back Vs Smartphones of Today. The Star Online. Retrieved from https://bit.ly/2gVW2Lm

Manjoo, F. (2014, March 12). A Wild Idea: Making Our Smartphones Last Longer. The New York Times. Retrieved from https://nyti.ms/2K156bk

Rahim, A., Safin, S. Z., Law, K. K., Abas, N., & Ali, S.M. (2016). Factors Influencing Purchasing Intention of Smartphone among University Students. Rahim, A., Safin, S. Z., Kheng, L. K., Abas, N., & Ali, S. M. (2016). Factors influencing purchasing intention of Smartphone among university students. Procedia \Economics and Finance, 37, 245-253.

Shrestha, S. (2016). Influencing Factors on Consumer Buying Behaviour of Smart Phones – A research on the buying behaviour of young consumer in Kathmandu, Nepal (Bachelor's thesis International Business Bachelor of Business Administration (BBA), Turku University of Applied Sciences, Nepal). Retrieved from https://bit.ly/2sJQoib

Ware, R. (2018, August 23). What is a Cellphone? Retrieved from https://bit.ly/2J9llvk