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# Multi-Criteria Decision Making in the Selection of Mobile Network Operators with AHP-TOPSIS Model

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**Abstract:** Mobile network operator is a provider of services wireless communications to the end users. Maxis, DiGi, Celcom and U Mobile are the main mobile network operators in Malaysia. Monthly bill charges, data services, peer and family influence, network coverage, customer service, rewards and value-added services are the major decision criteria in the selection of mobile network operators. The objective of this study is to determine the most preferred mobile network operator among Maxis, DiGi, Celcom and U Mobile with Analytic Hierarchy Process-Technique for Order of Preference by Similarity to Ideal Solution (AHP-TOPSIS) Model. Besides that, this study aims to identify the priority of decision criteria in the selection of mobile network operators. AHP-TOPSIS Model is a decision making model which helps to determine the best alternatives based on multiple criteria. The results of this study show that Maxis is the most preferred mobile network operator followed by DiGi, U Mobile and Celcom. Furthermore, monthly bill charges and data services are the most influential criteria in this study. The significance of this study is to identify the most preferred mobile network operators in Malaysia and the most important criteria in decision making process.

**Key words:** Multi-criteria decision making, AHP-TOPSIS Model, mobile network operator, priority, services wirless communications, influential criteria

## INTRODUCTION

Mobile network operator is a provider of services wireless communications to the end users. Maxis, DiGi, Celcom and U Mobile are the main mobile network operators in Malaysia. In decision making process for the selection of mobile network operator, the consumers need to consider the important criteria that affect the choice of mobile service providers (Alam *et al*., 2012). Based on the past studies, monthly bill charges, data services, peer and family influence, network coverage, customer service, rewards as well as value-added services are the main decision criteria for the selection of mobile network operators. The objective of this study is to determine the most preferred mobile network operator among Maxis, DiGi, celcom and U mobile by using Analytic Hierarchy Process-Technique for Order of Preference by Similarity to Ideal Solution (AHP-TOPSIS) Model. Besides that this paper also aims to identify the priority of the decision criteria in the selection of mobile network operators. AHP-TOPSIS Model is a decision making model which helps to determine the best alternatives based on multiple criteria (Velasquez and Hester, 2013). The rest of the research is organized as follows.

**Literature review:** One of the major factors to be considered is monthly bill charges or commitment which plays an important role in the telecommunication industry (Kollmann, 2000). It covers the call and texting charges, buying price as well as monthly rental charges. The customers can choose from a variety of service providers in a market dominated by price or monthly bill charges as they can make a full pricing comparison. Mobile data traffic, driven by the increase in the usage of smart devices is growing drastically as there is a higher demand for dataservices.

The influences from family, peer and social media are important decision criteria in the selection of mobile network operators. Isaksen and Roper (2012) concluded that possessing a certain material may be the fastest way to gain acceptance among peers and intimate friendships. In this era, the social media made a significant influence on purchasing decisions with consumers are more likely to purchase items based on the benchmark available on

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social media. Besides that network coverage also gives a serious impact on the quality of services. Leisen and Vance (2001) agreed that the quality of service assists to develop the essential competitive advantage by becoming the effective factor for differentiation. Customer service is one of the most vital essences of the product and services marketing. Customer loyalty can be developed and further strengthened through high quality customer service. The customers do not emphasize on the product of interest and instead, they focus on the additional elements of service provided (Sheth and Parvatiyar, 1995).

Rewards are things offered to customers by a service provider in recognition of their loyalty and achievements. Consumers normally are willing to invest their time, money and effort in order to gain a chance towards any reward of an uncertain extent. The motivation towards a reward of known extent is lower than a reward of uncertain extent (Shen *et al*., 2015). As a result, the rewards bring excitement and higher motivation to consumers. Therefore, rewards can be a significant factor for the selection of mobile network operators. In addition, Value-Added Services (VAS) is one of the major income generators in the telecommunications industry. VAS is a term for non-core services which are beyond normal voice calls. Most customers have already started using the VAS provided by their respective mobile service providers and it has become a vital part in assisting customers in their daily lives.

Selection of mobile network operators is a multi-criteria decision making problem to the consumers. In order to make decision effectively, AHP-TOPSIS Model has been applied in various fields to solve the multi-criteria decision making problem (Yildiz and Yildiz, 2015; Mubarak *et al*., 2013; Bhutia and Phipon, 2012; Maliki and Owens, 2012). AHP-TOPSIS Model seeks to find the best alternative among multiple alternatives. AHP-TOPSIS Model is able to rank the alternatives and obtain the best alternative selection. The best alternative selection has the most distant solution from the negative ideal solution and also has the closest distance to the positive ideal solution.

Based on the past studies, AHP-TOPSIS Model has been applied in various fields in different countries. However, this model has not been studied actively for the selection of mobile network operators in Malaysia. Therefore, this study aims to fill the research gap by studying the selection of mobile network operators among Maxis, DiGi, Celcom and U Mobile in Malaysia with AHP-TOPSIS Model.

## MATERIALS AND METHODS

There are 3 stages in the selection of mobile network operators with AHP-TOPSIS Model as shown in Fig. 1:

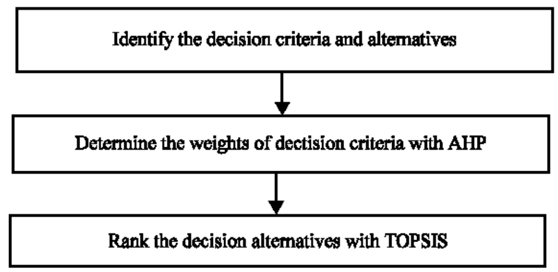


Fig. 1: Three stages in the selection of mobile network operators with AHP-TOPSIS Model

Table 1: Decision criteria for the selection of mobile network operator

| Decision criteria | Symbol |
|---|---|
| Monthly bill charges | $C_1$ |
| Data services | $C_2$ |
| Influence | $C_3$ |
| Network coverage | $C_4$ |
| Customer service | $C_5$ |
| Rewards | $C_6$ |
| Value-added-services | $C_7$ |

- Stage 1: identify the decision criteria and decision alternatives for the selection of mobile network operator
- Stage 2: determine the weights or priorities of the decision criteria with AHP
- Stage 3: rank the decision alternatives with TOPSIS and determine the best alternative

In this study, Maxis, DiGi, Celcom and U Mobile are selected as the decision alternatives. Monthly bill charges, data services, peer and family influence, network coverage, customer service, rewards as well as value-added services are the seven decision criteria identified for the selection of mobile network operators as shown in Table 1. The data consists of 300 respondents who are the users of mobile network operators in Malaysia.

**Analytic Hierarchy Process (AHP):** AHP is a multi criteria decision making tool for analyzing and solving complex decision making problem (Saaty, 1980). In this study, AHP is applied to determine the weights or priorities of the decision criteria in the selection of mobile network operators. The steps of AHP are shown as follows.

**Step 1:** Construct the pairwise comparison matrix. Each criterion is compared in pairwise to obtain its relative importance to the problem. The ratio scale for pairwise comparison (Winston and Goldberg, 2004) is presented in Table 2. A pairwise comparison matrix **C** for n decision criteria is presented below:

Table 2: Ratio used for pairwise comparison

| Scales | Definition |
|---|---|
| 1 | A and B are of equal importance |
| 3 | Experience and judgment slightly favour A over B |
| 5 | A is of essential or strong importance than B |
| 7 | A is favoured very strongly over B |
| 9 | A is of absolute importance than B |
| 2, 4, 6, 8 | Intermediate values |

$$C = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ \vdots \\ C_n \end{array}\begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 & \dots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \dots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & \vdots & 1 \end{bmatrix} \end{array}$$

**Step 2:** Construct the normalized decision matrix:

$$c_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}, i = 1, 2, 3, ..., n, j = 1, 2, 3, ..., n \quad (1)$$

**Step 3:** Construct the weighted normalized decision matrix to determine the weights or priorities of the decision criteria:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} c_{ij}, i = 1, 2, 3, ..., n \quad (2)$$

**Step 4:** Calculate the Consistency Ratio (CR) which is defined in terms of Consistency Index (CI) and Random Index (RI) as follows:

$$CR = \frac{CI}{RI} \quad (3)$$

CI is defined as:

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

Where:

$\lambda_{max}$ = The maximum eigenvalue

n = The number of decision criteria

Table 3 shows the Random Index (RI) with respect to the number of decision criteria (Winston and Goldberg, 2004). If CR<0.10, the level of consistency in the pairwise comparison matrix is satisfactory and therefore, the result is acceptable.

**Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS):** TOPSIS Model was developed by Hwang and Yoon (1981) and used in this study in order to determine the most preferred selection of mobile network operator. Basically, TOPSIS Model is able to rank the alternatives and obtain the best alternative selection. The best alternative selection has the most distant solution from the negative ideal solution and also has the closest distance to the positive ideal solution. The steps of TOPSIS are shown as follows.

Table 3: Values of random index

| n | RI |
|---|---|
| 2 | 0.00 |
| 3 | 0.58 |
| 4 | 0.90 |
| 5 | 1.12 |
| 6 | 1.24 |
| 7 | 1.32 |
| 8 | 1.41 |
| 9 | 1.45 |
| 10 | 1.51 |

**Step 1:** Construct the decision matrix which consists of m alternatives and n decision criteria. The score of each alternative with respect to each criterion is given as $x_{ij}$ and then a decision matrix $(x_{ij})$ as formed:

$$(x_{ij})_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \quad (5)$$

**Step 2:** Construct the normalized decision matrix as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}, i = 1, 2, ..., n, j = 1, 2, ..., m \quad (6)$$

**Step 3:** Construct the weighted normalized decision matrix by multiplying the weights $w_i$ of the decision criteria with the normalized decision matrix $r_{ij}$:

$$t_{ij} = w_i r_{ij}, i = 1, 2, ..., n, j = 1, 2, ..., m \quad (7)$$

**Step 4:** Determine the positive (best) ideal solution $A_b$ and negative (worst) ideal solution $A_w$ as follows:

$$A_b = \{\langle \min (t_{ij} \mid i = 1, 2, ..., m) \mid j \in J_-\rangle, \langle \max (t_{ij} \mid i = 1, 2, ..., m) \mid j \in J_+\rangle\} \equiv \{t_{bj} \mid j = 1, 2, ..., n\} \quad (8)$$

$$A_w = \{\langle \max (t_{ij} \mid i = 1, 2, ..., m) \mid j \in J_-\rangle, \langle \min (t_{ij} \mid i = 1, 2, ..., m) \mid j \in J_+\rangle\} \equiv \{t_{wj} \mid j = 1, 2, ..., n\} \quad (9)$$

Where:

$J_+$ = The {j = 1, 2, ..., n|associates with the decision criteria having a positive impact

$J_-$ = The {j = 1, 2,..., n| associates with the decision criteria having a negative impact

**Step 5:** Calculate the separation measures for each alternatives from the positive ideal solution $d_{ib}$ and negative ideal solution $d_{iw}$ as follows:

$$d_{ib} = \sqrt{\sum_{j=1}^{n}(t_{ij} - t_{bj})^2}, i = 1, 2, ..., m \tag{10}$$

$$d_{iw} = \sqrt{\sum_{j=1}^{n}(t_{ij} - t_{wj})^2}, i = 1, 2, ..., m \tag{11}$$

**Step 6:** Calculate the relative closeness coefficient to the ideal solution for each alternative as follows:

$$s_{iw} = \frac{d_{iw}}{d_{ib} + d_{iw}}, i = 1, 2, ..., m \tag{12}$$

**Step 7:** Rank the alternatives based on the relative closeness coefficient $s_{iw}$ in descending order. The alternative with the highest $s_{iw}$ is the best alternative. $s_{iw} = 0$ if and only if the alternative solution has the worst condition whereas $s_{iw} = 1$ if and only if the alternative solution has the best condition.

## RESULTS AND DISCUSSION

Figure 2 shows the weights or priority of all decision criteria in the selection of mobile network operators. Based on Fig. 2, the priority of decision criteria in the selection of mobile network operator is the monthly bill charges (0.245) followed by data services (0.216) influence (0.197) network coverage (0.195) customer service (0.071) rewards (0.042) and finally value-added services (0.034). The result shows that monthly bill charges and data services are the most influential decision criteria in the selection of mobile network operator. In this study, the consistency ratio is 0.05 which is well below 0.10. This implies that the pairwise comparison matrix does not exhibit any significant inconsistency and therefore, the result is acceptable.

The distance of all alternatives from positive ideal solution ($d_{ib}$) and the distance of all alternatives from negative ideal solution ($d_{iw}$) are calculated by using the Eq. 10 and 11, respectively. The distance of all alternatives from positive ideal solution ($d_{ib}$) for Maxis, DiGi, Celcom and U Mobile are 0.0391, 0.0475, 0.1746 and 0.1512,

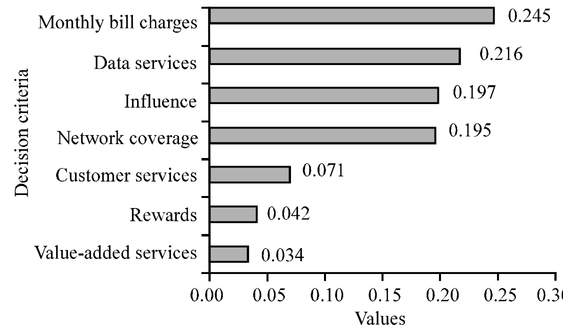


Fig. 2: Priority of decision criteria in the selection of mobile network operators

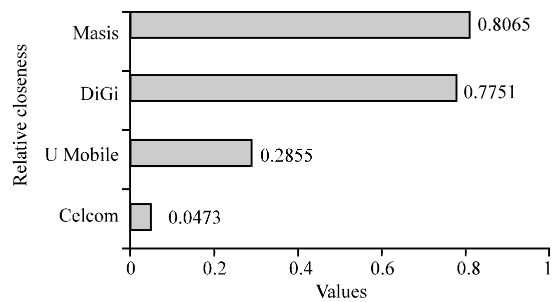


Fig. 3: Relative closeness coefficient to the ideal solution of mobile network operator

Table 4: Ranking of mobile network operator

| Rank | Mobile network operator | Relative closeness coefficient |
|---|---|---|
| 1 | Maxis | 0.8065 |
| 2 | DiGi | 0.7751 |
| 4 | Celcom | 0.0473 |
| 3 | U Mobile | 0.2855 |

respectively. On the other hand, the distance of all alternatives from negative ideal solution ($d_{iw}$) for Maxis, DiGi, Celcom and U Mobile are 0.1629, 0.1637, 0.0087 and 0.0604, respectively. Figure 3 and Table 4 present the relative closeness coefficient to the ideal solution and the ranking of mobile network operator. As shown in Fig. 3 and Table 4, the relative closeness coefficient to the ideal solution, $s_{iw}$ for Maxis is 0.8065 which is the highest compared to other mobile network operators. Therefore, Maxis is the most preferred mobile network operator with respect to all decision criteria which are monthly bill charges, data services, influence, network coverage, customer service, rewards and value-added services. The relative closeness coefficient to the ideal solution, $s_{iw}$ for DiGi, Celcom and U Mobile are 0.7751, 0.0473 and 0.2855, respectively. This implies that the preference of the mobile network operators is followed by DiGi, U Mobile and finally Celcom.

## CONCLUSION

Maxis is the most preferred mobile network operator followed by DiGi, U Mobile and Celcom with respect to monthly bill charges, data services, peer and family influence, network coverage, customer service, rewards as well as value-added services. Monthly bill charges is ranked as the most influential decision criterion in this study. The priority of the decision criteria is followed by data services, influence, network coverage, customer service, rewards and value-added services.

The significance of this study is to identify the most preferred mobile network operator in Malaysia and the most important decision criteria in decision making process. In addition, this study also helps other less favourable mobile network operators such as U Mobile and celcom to identify the potential improvements based on the most influential decision criteria.

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