# A Fuzzy Topsis Approach for Selecting Mobile Banking Applications

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## ABSTRACT

The growing reliance on mobile banking applications has created challenges for users in selecting the most suitable option due to diverse features and services tailored to varying preferences. Similarly, banks and application developers struggle to successfully customize their applications to satisfy user needs effectively. This study aimed to rank mobile banking applications among UiTM Perlis students using the Fuzzy Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) approach. Additionally, it sought to identify and rank the criteria influencing the selection of mobile banking applications. Primary data were collected from 55 UiTM Perlis through an online questionnaire. This study focused on three mobile banking applications as the alternatives which were MAE by Maybank2u, GO by Bank Islam, and RHB Mobile Banking, and evaluated them based on four criteria which were design, efficiency, security, and customer support. The results of the Fuzzy TOPSIS analysis revealed that MAE by Maybank2u emerged as the top-ranked application, followed by RHB Mobile Banking and GO by Bank Islam. These findings are highly significant as they provide valuable insights for banks and developers to refine their applications by focusing on key user preferences, such as enhanced design, improved efficiency, robust security, and better customer support. Users benefit from improved mobile banking experiences that align with their expectations for convenience and functionality. Furthermore, this research highlights the importance of understanding user preferences as a strategic advantage in a competitive market. Future research should expand the sample size to include participants from diverse regions to ensure more generalizable results. Incorporating qualitative feedback can also offer deeper insights into user satisfaction, enriching the understanding of how mobile banking applications can be improved to meet evolving user demands effectively.

**Keywords**: Fuzzy TOPSIS, Mobile Banking Application, Selection. Students

## INTRODUCTION

Technology plays an important role in our daily lives and society in this modern era (Ubam et al., 2021). According to the ABA Banking Journal, the American Bankers Association reports that the pandemic significantly increased the adoption of digital banking technology. Globally, COVID-19 accelerated the digital transformation across all industries (Oh & Kim, 2021). Before the pandemic, financial institutions slowly implemented indirect services, including ATMs and Internet banking, to increase customer convenience and ease of use. However, due to the pandemic, traditional banks are facing challenges in enhancing customer satisfaction through mobile banking services since the demand for virtual services has grown. According to health recommendations, minimizing close interactions is an effective way to control the COVID-19 epidemic. Consequently, most banks in the countries that were affected have shortened their branch hours and encouraged customers to use mobile banking services (Nair et al., 2021).

Currently, more than 60.42% of people worldwide use smartphones (Turner, 2022) . Smartphones and the Internet are available to everyone in developed countries (Islam et al., 2020). Meanwhile, current research

indicates an increase in the usage of smartphones and the Internet in developing countries (Karim et al., 2017). Innovations like smartphones connected to the Internet allow us to easily access various services whenever and wherever (Ubam et al., 2021). Therefore, the banking industry follows the technological advancement to develop mobile banking applications that enhance their customers' experience and resolve technical problems.

Oh and Kim (2021) stated that mobile banking applications are one of the newest digital technologies that combine financial services with mobile communication. Financial organizations develop mobile applications that help customers perform any kind of financial activity such as payments, banking transactions, portfolio management, bill payments, and balance inquiries (Majumdar & Pujari, 2022). With all of these, customers can conduct banking transactions anytime and anywhere, reduce expenses, and increase the accessibility of money, especially for people who live in rural areas (Kanungo & Gupta, 2021 ;Thakuri et al., 2023). Using technology, financial institutions can also benefit since it can standardize service delivery, expand the options available to their service providers, lower costs, and decrease the workload on their branches (Saprikis et al., 2022). However, there are a lot of criteria that should be considered to ensure that customers still use the application. As an illustration, ease of use, trustfulness, learnability, memorability, satisfaction, collaboration, security, customer support, navigational design, efficiency, and login time (Hussain et al., 2014 ;Kapoor & Vij, 2020).

The use of mobile banking applications has increased in Malaysia. Central Bank of Malaysia Annual Report states that as of 2022, Malaysians were using the Internet and mobile banking transactions 7.2% more than in 2021. Since there are up to eighteen banks in Malaysia that provide mobile and online banking services, they must compete to ensure that the applications have fulfilled their customers. Selecting the best mobile banking application that is suitable to customers' preferences and needs is challenging as well. Therefore, ranking banks based on different criteria using the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) can be implemented.

Mobile banking applications are a recent innovation that has grown in popularity since their introduction to the banking industry (Esmaeili et al., 2021). However, although mobile banking applications are becoming increasingly popular, banks and mobile banking application developers still do not fully understand why users choose one application over another (Komulainen & Saraniemi, 2019). This indicates that banks and mobile banking application developers are not clear on how to improve their applications for users. The development of applications needs to understand the needs, objectives, and concepts of the target user (Alhejji et al., 2022).

In addition, with so many alternatives on the market, choosing the best mobile banking application for their specific needs and interests has become more difficult for users. Each person has unique needs and interests, which makes it even harder to select a mobile banking application. For this reason, it is essential to study the criteria that influence the selection of mobile banking among students of UiTM Perlis by using fuzzy TOPSIS. This method will be used to determine the preferred mobile banking applications based on different criteria.

## LITERATURE REVIEW

### Mobile Banking Application

Saprikis et al. (2022) defined a mobile banking application as a system for customers to download and perform various banking operations on their mobile devices. Recent technological innovations in mobile banking applications have an opportunity to enhance the banking experience of financial institutions and speed up the banking process (Thusi & Maduku, 2020). In this study, only three mobile banking applications will be investigated which are MAE by Maybank2u, GO by Bank Islam, and RHB Mobile Banking. Sam et al. (2023) indicated that the Maybank application is the most preferable mobile banking application to most Malaysians.

### Selection of Mobile Banking Application

As the technology is still new and the related problems are changing quickly, it is difficult for financial institutions to understand the problems. Many criteria influence the selection of mobile banking applications such as log-in time, ease of use, security, visual design, information design, convenience, navigational design,

customer support, and collaboration design (Kapoor & Vij, 2020;Oh & Kim, 2021). However, only four criteria will be investigated which are design, efficiency, security, and customer support.

**Design**

Hussain et al. (2014) stated that the mobile application needs to be made in a way that makes it possible for users to use the application effectively. Creating a simple and clear interface helps to increase accessibility. As stated in Kapoor and Vij (2020), navigational design refers to the pages' structure arrangement and content. Users prefer simple, clear navigation that allows them to find what they are looking for quickly and finish transactions in the fewest possible steps. Customers' trust in service providers may be lost by a poorly designed interface. An attractive visual website design provides customers with a positive impression of the quality of the company and its products. An application with a better visual design would have attracted users. Studies indicate that users are unwilling to use mobile applications that have low interface design.

**Efficiency**

Efficiency is the capability of customers to finish a task accurately and quickly. Efficiency can be evaluated in various ways, such as the amount of time spent on each screen, the time needed to finish a job or series of tasks, and the frequency of errors made by the customers (Weichbroth, 2020). This illustrates how productive a customer is when using the application (Harrison et al., 2013). Regarding smartphones, the user experience is significantly improved by the application's loading page. Loading time refers to how long it takes for applications to load on a smartphone and how quickly they respond to the users when they load and use the application (Hussain et al., 2014). Users often become irritated and may even close the page when they experience loading times. Therefore, the loading screen design must be improved because it influences the user experience (Wang et al., 2021). According to Weichbroth (2020), efficiency is the most common criterion that influences the usability of mobile banking applications.

**Security**

According to Thakuri et al. (2023), security is information protection and safety. Users are happier with the service when they perceive their financial transactions are secure (Raza et al., 2017). Recently, numerous banks have included fingerprint and facial recognition in their mobile applications to improve users' availability and convenience. Although recognition is easy and fast, hackers can still exploit it. Therefore, banks should achieve a balance between customer convenience and security (Oh & Kim, 2021). Mobile banking applications have an automatic time-out feature in which the user will automatically be logged out of their online banking session if they have been inactive for several minutes. Referring to the results, they showed that security and trustworthiness are the most important factors that influence user ratings and satisfaction (Chanu & Singh, 2022 ; Oh & Kim, 2021).

**Customer Support**

Customer support can be defined as the retail bank's online chat service, online requests like creating a Personal Identification Number (PIN) or resolving chequebook issues, and various interactions, that connect a customer to the bank, like e-mail service, online support, online requests, queries, and complaint management, etc (Kapoor & Vij, 2020). When mobile banking applications and the bank can solve customers' problems through seamless communication, they can build trust. However, when customers experience rude service or delayed communication with customer care, they may lose trust in banks. Unhappy customer service interactions could lead to low ratings of the mobile banking applications (Oh & Kim, 2021).

A summary of past studies done to determine the mobile application criteria is shown in Table 1.

Table 1 : Summary of past study on the the mobile application criteria

| Article | Mobile Application Criteria. |
|---|---|
| (Hussain et al., 2014) | Effectiveness, Learnability, Efficiency and trustfulness. |

| | |
|---|---|
| (Başar & Kul, 2020) | Effectiveness, Efficiency and Satisfaction |
| (Kapoor & Vij, 2020) | Login time, Information Design, Collaboration, Service Quality, Visual Design and Navigational Design. |
| (Weichbroth, 2020) | Effectiveness, Memorability, Efficiency and Satisfaction, Ease of use, Cognitive Load, Simplicity, Learnability and Errors |
| (Oh & Kim, 2021) | Ease of use, Security, Customer support and Convenience. |
| (Chanu & Singh, 2022) | Perceived Usefulness, Ease of Use, Security, Trust, Intention to Use, Adoption of E-Banking and Attitude. |
| (Thakuri et al., 2023) | Security, Responsiveness, Convenince, Cost, Relative Advantages and Customer Satisfaction. |

**Multi-Criteria Decision Making**

Over the past few years, multi-criteria decision-making (MCDM) has experienced rapid growth (Aliyev et al., 2020). Since MCDM techniques usually take into both quantitative and qualitative factors, decision-makers can use those kinds of selection-influencing criteria (Khodamipour et al., 2022). A decision maker can rank a finite collection of alternatives using MCDM, and they also can weigh a finite set of criteria according to the relative importance obtained. Choosing the right alternative requires consideration of several criteria. This technique is extremely useful when dealing with selection difficulties involving various selection criteria. Therefore, MCDM is a comprehensive field that offers a useful method for rating options in complex decision-making situations. When the appropriate decision- making problem criteria are met, the expected result can be obtained (Aliyev et al., 2020).

**Fuzzy TOPSIS**

Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) is one of the traditional MCDM approaches developed by Hwang and Yoon (1981). TOPSIS frequently applied to rank the problems that consider both positive and negative ideal solutions. Memari et al. (2019) indicated that the TOPSIS method seems more straightforward and easier to understand in contrast to other methods like Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and ELimination and Choice Expressing Reality (ELECTRE).

In conventional TOPSIS method formulation, individual evaluations are expressed as crisp values. However, measuring with crisp values is not always practicable in the real world (Khodamipour et al., 2022). Most decision-making problems are defined by fuzziness and vagueness (Yu, 2002). Instead of using crisp value, it might be preferable to use linguistic value. Linguistic values can be presented using fuzzy set theory. Therefore, fuzzy TOPSIS was developed to handle confusion in decision-maker judgments and evaluations better and more appropriate (Kannan et al., 2014;Prakash & Barua, 2015).

The fuzzy TOPSIS method is useful in solving problems for individuals and groups. When it comes to group decision-making, the outcome is achieved through a combination of the decisions made by all decision-makers (Unvan, 2020). According to NĂdĂban et al. (2016), TOPSIS in a fuzzy environment is introduced to address human judgement and confusion in making decisions. In this context, decision-makers must make decisions without having any knowledge of the possible outcomes. Based on the linguistic variables, decision-makers must rank, select, or rate these alternatives against the criteria. Then it will be transformed into fuzzy numbers. With that, the aggregate fuzzy numbers are computed. Since we aim to obtain the most consistent results, we addressed the mobile banking application selection problem within the fuzzy environment.

**The Application of Fuzzy TOPSIS to Evaluate Mobile Banking Applications**

The application of Fuzzy TOPSIS can be implemented in various situations to solve decision-making problems. There is one study that have used fuzzy TOPSIS to solve this related problem. Roy and Shaw (2023) was employed the Fuzzy TOPSIS approach to rank nine mobile banking applications in India. These alternatives were evaluated based on thirty sub-criteria under three criteria which are ease of use, usefulness, and riskiness.

This study used seven experts as their respondents. This paper indicates that the usefulness of mobile banking applications and ease of use have emerged as the two most important factors in selecting mobile banking applications. As a result, the PayZapp application (A2) was determined as the best mobile banking application among ten mobile banking applications in India.

## METHODOLOGY

This study aimed to identify UiTM Perlis students' mobile banking application preferences. This study uses primary method of data collection that was distributed to 55 respondent, encompassing UiTM Perlis students with different faculties. According to Halim and Ishak (2014), it is noted that a sample size that falls somewhere between 30 and 500 would be suitable for most of the research. The online questionnaire consisted of two sections. Part A cover mobile banking preference while Part Bart B requires respondent to rank the criteria and alternatives of mobile banking application based on each criterion using linguistic variables as listed in Tables 1 and 2 (NĂdĂban et al., 2016). The alternatives are mobile banking applications were GO by Bank Islam, MAE by Maybank2u and RHB Mobile Banking. Meanwhile, the criteria are design, efficiency, security and customer support. Figure 1 shows all the criteria and alternatives for selection of mobile banking application.

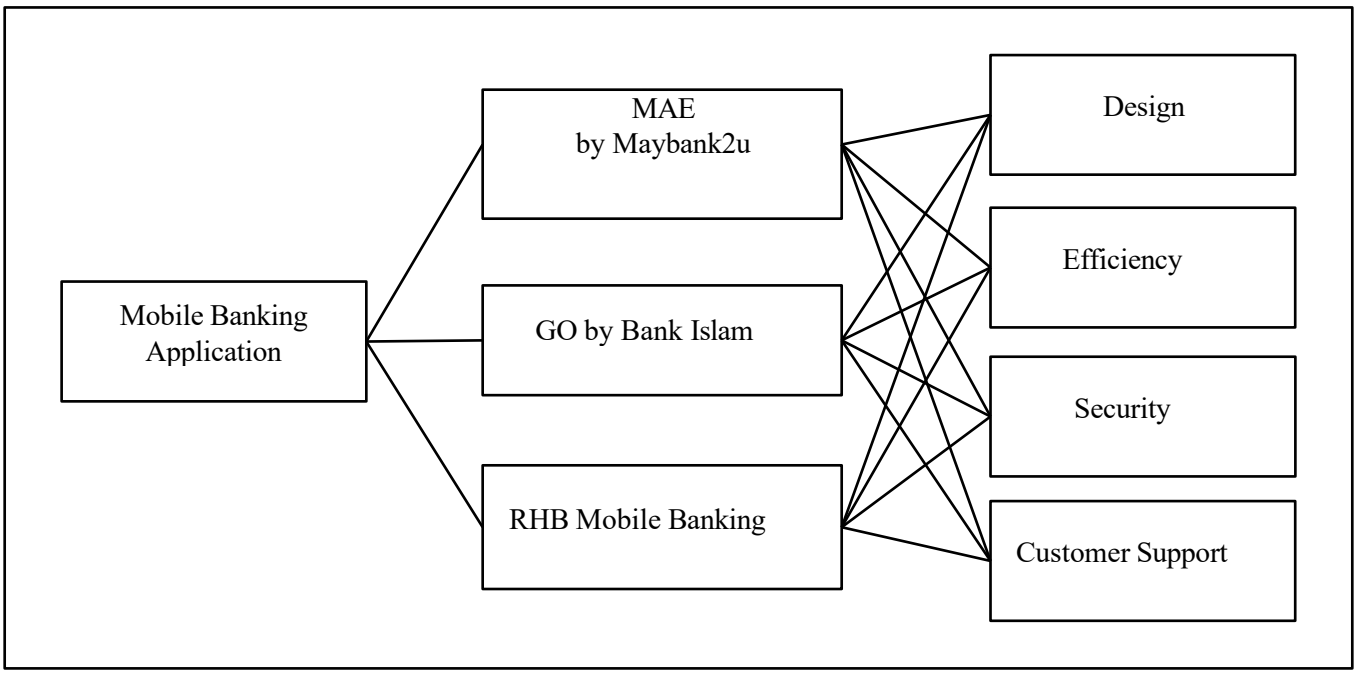


Figure 1: Hierarchy structure for selection of mobile banking application

Table 2: Linguistic Variable for the important of criteria

| Linguistic variables | Triangular Fuzzy Number |
|---|---|
| Not important at all | (0.00,0.10,0.30) |
| Slightly important | (0.10,0.30,0.50) |
| Moderately Important | (0.30,0.50,0.75) |
| Important | (0.50,0.75,0.90) |
| Very important | (0.75,0.90,1.00) |

Table 3: Linguistic Variable for the alternatives based on criteria

| Linguistic variables | Ratings value | Triangular Fuzzy Number |
|---|---|---|
| Very poor | 1 | (1,1,3) |
| Poor | 2 | (1,3,5) |
| Medium | 3 | (3,5,7) |
| Good | 4 | (7,9,10) |
| Very good | 5 | (9,10,10) |

**Steps in Fuzzy TOPSIS**

Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) was applied in the decision-making process of this study. In accordance with Mahmud et al. (2018), there are five steps involved in this study.

**Step 1**: Group of decision makers are formed and the rating for the criteria and alternatives are assigned by the decision makers.

Assume that in this a group of decision makers of $K$ respondents will be formed. The fuzzy rating of alternatives $A_i$ denoted $x_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$ and the weight of criterion $C_j$ is denoted $w_j = \left(w_{j1}, w_{j2}, w_{j3}\right)$. The fuzzy numbers for each criterion and alternatives were assigned. Then, the average fuzzy numbers for each alternative and the average fuzzy weight of each criterion were calculated. The average fuzzy numbers for the alternatives of $i^{th}$ alternative with respect to $j^{th}$ criterion is given as follows:

$$x_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right);\ i = 1, 2, ....., m \quad j = 1, 2, ....., n \tag{1}$$

$$w_j = \left(w_{j1}, w_{j2}, w_{j3}\right); j = 1, 2, ...., n \tag{2}$$

$$a_{ij} = \frac{1}{K}\sum_{k=1}^{K} a_{ij}^{k},\quad b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^{k},\quad c_{ij} = \frac{1}{K}\sum_{k=1}^{K} c_{ij}^{k} \tag{3}$$

$$w_{j1} = \frac{1}{K}\sum_{k=1}^{K} w_{j1}^{k},\quad w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^{k},\ w_{j3} = \frac{1}{K}\sum_{k=1}^{K} w_{j3}^{k} \tag{4}$$

$x_{ij}$ and $w_j$ are the linguistic values that can be conveyed by the triangular fuzzy numbers as shown in Table 2 and Table 3 respectively.

**Step 2**: The normalized fuzzy decision matrix was constructed.

The normalized fuzzy decision matrix is $R = \left[\tilde{r}_{ij}\right]$, $i = 1, 2, ..., m$, $j = 1, 2, ..., n$

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^{+}}, \frac{b_{ij}}{c_j^{+}}, \frac{c_{ij}}{c_j^{+}}\right),\ c_j^{+} = \max_i \left\{c_{ij}\right\} \text{ (benefit criteria)} \tag{5}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^{-}}{c_{ij}}, \frac{a_j^{-}}{c_{ij}}, \frac{a_j^{-}}{c_{ij}}\right),\ a_j^{-} = \min_i \left\{a_{ij}\right\} \text{ (cost criteria)} \tag{6}$$

**Step 3**: The weighted normalized fuzzy decision matrix was constructed:

The weight normalized fuzzy decision matrix is $V = \left[\tilde{v}_{ij}\right]$, $i = 1, 2, ...., m,\ j = 1, 2, ...., n$

$$\text{Where } \tilde{v}_{ij} = \tilde{r}_{ij} \times w_j \tag{7}$$

**Step 4**: The Fuzzy Positive Ideal Solution (FPIS $A^+$) and Fuzzy negative Ideal Solution (FNIS $A^-$) were determined as follows:

$$A^+ = \left(\tilde{v}_1^+, \tilde{v}_2^+, ..., \tilde{v}_n^+\right), \quad \tilde{v}_j^+ = \max_i \left\{v_{ij}\right\}, i = 1,2,3,....,m \ , j = 1,2,3,....., n \tag{8}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_n^-\right), \quad \tilde{v}_j^- = \min_i \left\{v_{ij}\right\}, i = 1,2,3....,n \ , j = 1,2,3,....., n \tag{9}$$

The distance for each alternative from FPIS and FNIS was calculated. The distance between two fuzzy triangular numbers is

$$d(a,b) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \tag{10}$$

Then, the fuzzy distance of each alternative from fuzzy positive, $d_x^+$ and fuzzy negative ideals solution, $d_x^-$ calculated as:

$$d_x^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^+\right) \tag{11}$$

$$d_x^+ = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \tag{12}$$

**Step 5**: The closeness coefficient for each alternative was calculated and the alternatives were ranked based on the closeness coefficient.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{13}$$

## RESULTS AND DISCUSSIONS

The results were generated from the method of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) using the steps given in methodology. There are five steps in this method. The steps and results are expressed in Table 4 until Table 10.

Step 1: A group of decision-making committees of 55 respondents who are familiar with alternatives given are chosen among the students of UiTM Perlis. The alternatives $A_i$ are chosen to rank, namely MAE by Maybank2u, Go by Bank Islam, and RHB Mobile Banking. Besides, Main criteria $C_j$ also are chosen to evaluate which are design, efficiency, security and customer support. With that, three alternatives are identified as $A_1$, $A_2$, and $A_3$ respectively with four criteria as $C_1, C_2$, $C_3$ and $C_4$ respectively .The average fuzzy numbers for each alternative

and the average fuzzy weight of each criterion were calculated using Equation (1) and Equation (2) are as table below:

Table 4: Average fuzzy numbers for alternative

| Alternatives | Criteria | | | |
|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
| $A_1$ | (7.36, 8.65, 9.20) | (7.18, 8.55, 9.16) | (6.49, 7.93, 8.76) | (6.67, 8.20, 9.00) |
| $A_2$ | (4.24, 6.18, 7.78) | (2.96, 4.91, 6.73) | (4.16, 6.09, 7.73) | (4.27,6.07, 7.62) |
| $A_3$ | (4.96, 6.75, 8.13) | (5.36, 7.20, 8.49) | (5.22, 6.98, 8.25) | (4.71, 6.51, 7.95) |

Table 5: Average fuzzy weight for criterion

| Criteria | Fuzzy Weight | The Important of Criterion |
|---|---|---|
| $C_1$ (Design) | (0.31, 0.52, 0.70) | 3 |
| $C_2$ (Efficiency) | (0.54, 0.75, 0.90) | 2 |
| $C_3$ (Security) | (0.59, 0.77, 0.91) | 1 |
| $C_4$ (Customer Support) | (0.20, 0.41, 0.62) | 4 |

**Step 2**: The normalized fuzzy decision matrix for benefit criteria and cost criteria.

The values for the normalized decision matrix of benefit criteria were calculated using Equation (5) while the value for the normalized decision matrix of cost criteria was computed using Equation (6). Table 6 show the results of the normalized fuzzy decision matrix.

Table 6: Normalized fuzzy decision matrix

| Alternatives | Criteria | | | |
|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
| $A_1$ | (0.80, 0.94, 1.00) | (0.78, 0.93,1.00) | (0.74, 0.90, 1.00) | (0.74, 0.91, 1.00) |
| $A_2$ | (0.46, 0.67, 0.85) | (0.32, 0.54, 0.73) | (0.48, 0.70, 0.88) | (0.47, 0.67, 0.85) |
| $A_3$ | (0.54, 0.73, 0.88) | (0.59, 0.79, 0.93) | (0.60, 0.80, 0.94) | (0.52, 0.72, 0.88) |

**Step 3**: The weighted normalized fuzzy decision matrix

Equation (7) was used to generate the weighted normalized fuzzy decision matrix which is presented in Table below.

Table 7: Weight Normalized fuzzy decision matrix

| Alternatives | Criteria | | | |
|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ |
| $A_1$ | (0.25, 0.49, 0.70) | (0.42, 0.70, 0.90) | (0.43, 0.70, 0.91) | (0.15, 0.37, 0.62) |
| $A_2$ | (0.14, 0.35, 0.60) | (0.17, 0.40, 0.66) | (0.28, 0.53, 0.81) | (0.10, 0.27, 0.52) |
| $A_3$ | (0.17, 0.38, 0.62) | (0.31, 0.59, 0.83) | (0.35, 0.61, 0.86) | (0.11, 0.29, 0.55) |

**Step 4**: The fuzzy distance of each alternative from fuzzy positive, $d_x^+$ and fuzzy negative ideals solution, $d_x^-$.

Table 8 and Table 9 show the shows the distance between two fuzzy triangular numbers from each alternative to the FPIS and FNIS. The fuzzy distance of each alternative was computed by using Equation (10), (11) and (12) while FPIS and FNIS values based on Equation (8) and Equation (9).

Table 8: The distance between two fuzzy triangular numbers from each alternative to the FPIS

| Alternatives | Criteria | | | | Total $d_x^+$ |
|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | |
| $A_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $A_2$ | 0.1190 | 0.2622 | 0.1436 | 0.0841 | 0.6089 |
| $A_3$ | 0.0912 | 0.0962 | 0.0751 | 0.0660 | 0.3285 |

Table 9: The distance between two fuzzy triangular numbers from each alternative to the FNIS

| Alternatives | Criteria | | | | Total $d_x^-$ |
|---|---|---|---|---|---|
| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | |
| $A_1$ | 0.1190 | 0.2622 | 0.1436 | 0.0841 | 0.6089 |
| $A_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $A_3$ | 0.0278 | 0.1680 | 0.0686 | 0.0182 | 0.2826 |

**Step 5**: The closeness coefficient for each alternative.

Table 10 shows the closeness coefficient was calculated by using Equation (13). Based on Table 9, the ranking order of these three alternatives is MAE by Maybank2u ( $A_1$ ), RHB Mobile Banking ( $A_3$ ) and GO by Bank Islam ( $A_2$ ) respectively.

Table 10: The closeness coefficient for five alternatives

| Alternatives | $d_x^+$ | $d_x^-$ | $CC_i$ | Rank |
|---|---|---|---|---|
| $A_1$ (MAE by Maybank2u) | 0.0000 | 0.6089 | 1.0000 | 1 |
| $A_2$ ( GO by Bank Islam) | 0.6089 | 0.0000 | 0.0000 | 3 |
| $A_3$ ( RHB Mobile Banking) | 0.3285 | 0.2826 | 0.4624 | 2 |

Table 10 presents the rankings of three mobile banking applications based on their proximity coefficients to the ideal solution. Among the evaluated alternatives, MAE by Maybank2u stood out as the top choice, achieving the highest closeness coefficient value of 1.0000. This perfect score indicates that MAE by Maybank2u is the best-performing application by showing that it most closely approaches the ideal solution based on the specified criteria. RHB Mobile Banking ranked second with a closeness value of 0.4624. The value performed moderately well but fell short of the ideal solution represented by MAE by Maybank2u. This significant gap highlights areas

for improvement. Despite its weaknesses, RHB Mobile Banking has strengths that make it a good option but needs improvements to compete better with the top-ranked application. On the other hand, GO by Bank Islam has a proximity coefficient of 0.0000, placing it in third place. With this score, GO by Bank Islam's mobile banking application falls short of the other alternatives in terms of fulfilling the evaluation criteria, making it the least preferred alternative. This low ranking highlights the potential areas in the application that should be improved to meet the needs and expectations of users. This study identified MAE by Maybank2u as the best mobile banking application among the three alternatives evaluated. Its top ranking reflects its ability to fulfill the criteria most effectively.

Table 5 highlighted the corresponding rankings of importance criteria, including design, efficiency, security, and customer support. The analysis provided valuable insights into the preferences of UiTM Perlis students when selecting mobile banking applications. Security emerged as the most important criterion in the evaluation process, underscoring its significance in shaping the decision-making of students. This finding indicated that UiTM Perlis students were concerned about the robustness and reliability of mobile banking applications. Security features such as fingerprint recognition, facial authentication, and automatic time-out were non-negotiable factors for these users. It showed that students were particularly mindful of safeguarding their financial data and ensuring safe transactions, making this criterion important in their overall evaluation. This insight underscored the need for mobile banking applications to prioritize a strong technical infrastructure to build user trust and confidence

## CONCLUSION

The primary objective of this study is to rank the selection of mobile banking applications among UiTM Perlis using Fuzzy TOPSIS method, focusing on platforms including MAE by Maybank2u, GO by Bank Islam, and RHB Mobile Banking. Additionally, the study seeks to identify the preferred mobile banking applications among UiTM Perlis students and the key criterion influencing the selection of mobile banking applications.mAmong the three evaluated applications, MAE by Maybank2u emerged as the top-performing application with a perfect closeness coefficient, making it the most aligned with the ideal solution. Its exceptional ranking signified its ability to meet user expectations across all criteria, making it the preferred mobile banking application. The finding is compatible with the findings in (Sam et al., 2023) that the Maybank2u application is the preferred mobile banking application. RHB Mobile Banking secured the second position with a competitive score, indicating solid performance but has potential for improvement to rival MAE by Maybank2u. In contrast, GO by Bank Islam ranked last, showing significant gaps in meeting the evaluation criteria and highlighting areas requiring immediate enhancement. These results showed that the main objective of this study was fulfilled.

The most significant criterion in choosing mobile banking applications, was also accomplished. The outcome showed that security was the most critical criterion, emphasizing the significance of security measures to safeguard users' financial information and ensure trustworthy transactions. This finding corresponded with (Oh & Kim, 2021; Chanu & Singh, 2022) that security was the most important factor that influenced user preferences and needs.

By utilizing the TOPSIS approach, this study systematically analyzed and ranked mobile banking applications based on their closeness to an ideal solution and their distance from a negative ideal solution. This methodology effectively simulated how users made decisions when selecting an application. These insights not only fulfilled the research objective by identifying the most preferred application but also solved the problem statement which provided a framework for banks and mobile banking application developers to understand user preferences and priorities within the broader mobile banking ecosystem.

The findings of this study on ranking mobile banking applications using the fuzzy TOPSIS methodology provide valuable insights and opportunities for further research. Future researchers can widen the scope of the study to include more mobile banking applications. By including other mobile banking applications, it could give a better understanding of user preferences and needs. Furthermore, to improve the depth and accuracy of the analysis, incorporating additional evaluation criteria could prove valuable. For example, transaction fees compatibility, or user data privacy could make the analysis more detailed and cover more criteria that affect users' choices.

Moreover, it is recommended that future studies explore other Fuzzy Multi-Criteria Decision-Making (FMCDM) approaches, such as Fuzzy Analytic Hierarchy Process (AHP), Fuzzy VIKOR, or Fuzzy ELECTRE, to rank mobile banking applications. These methods could provide new insights and help confirm the reliability of the findings, giving a more complete picture of how decisions are made in mobile banking. Lastly, incorporating qualitative research methods, such as user interviews or focus groups, alongside quantitative FMCDM analyses, could add valuable context to the findings. User feedback could provide insights into emotional and experiential factors that are difficult to quantify but play a significant role in application selection. By integrating qualitative and quantitative approaches, future studies could present a more comprehensive picture of user behavior, preferences, and priorities in the realm of mobile banking.

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