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Evaluating Mobile Wallet Adoption Barriers Using Fuzzy Mathematical Model

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Abstract: A tremendous amount of research has been done on the factors influencing mobile wallet adoption as mobile wallet technology has seen rapid growth. Using expert opinion and Fuzzy PROMETHEE approach, this study investigates the key barriers to mobile wallet adoption. Mobile wallet adoption is constrained by Technological, security and infrastructural barriers, making adoption more challenging when user acceptance is skewed in emerging markets. In this study, we use the F-PROMETHEE to rank these barriers based on expert opinions. A panel of fintech and digital payments experts assessed the key adoption obstacles. Included in the PROMETHEE method were methods for handling variability or uncertainty through fuzzy logic and through subjective expert judgments. The results suggest that the major barriers to the adoption of mobile wallets were identified as risk and usage constraints. Moreover, value barriers are a leading factor. This study found that the risk and value barriers are the two principal risks that must be overcome to raise the client accepted rate of m-wallet services. A step forward in the assessment of such obstacles is the innovative use of a fuzzy mathematical model, which provides a more complex and adaptable approach than traditional methods. This study has learnt a few lessons that can help policy makers and industry players understand how to overcome the main barriers to mobile wallet adoption.

Introduction

Today's explosion of mobile wallets has made it easy and simple for consumers to make purchases anywhere in the world. Although mobile wallets have gained in popularity, their adoption has been uneven within the markets and is hindered by a diversity of factors, including the preferences of consumers, technological infrastructure and regulatory frameworks. There is very much recent interest in the adoption of mobile wallets. Mobile wallets are an excellent way to exchange money and could even change the way we pay. The growth of mobile communication technology has been amazing in the last decade. Due to the limitations of traditional methods, there have been next-generation mobile technology-driven business solutions (Kunganathan and Wikramanayake, 2014). This contemporary payment approach allows users to conduct transactions digitally through mobile phones by entering a personal identification number at payment terminals (Kapoor et al., 2020).

Mobile wallet represents one of the service initiatives in this domain. This modern solution allows customers to perform electronic payments via mobile phone by entering a PIN code and tapping their smartphones on the payment terminal (Tang et al., 2014). Given the numerous advantages that m-wallet offers to users, it possesses the potential to supplant alternative payment methods (Leavitt, 2012). According to the 2024 Capgemini World Payment Report, mobile payment transaction volumes experienced a significant increase, reaching 1,411 billion in 2023, and estimates suggest the figure will increase to 1,650 billion by 2024. With a

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growing preference among consumers for seamless and frictionless payment methods, this upward trend is projected to continue, with mobile payment transactions expected to reach 2,838 billion by 2028.

Biswas and Pamucar (2023) improved the EDAS approach for use in uncertain decision-making by adding grey theory and picture-fuzzy logic. Contrary to emerging theories based on a few case studies, our findings show strong factors affecting M-Wallet choice, including user friendliness and features, and indicate the need for corresponding research on objective measurements and a broader study of consumer behavior.

In this research, Ajina et al. (2023) tried to find out the factors that would determine consumers' intention to adopt mobile wallet apps in Pakistan. Using two theories of mobile wallet adoption, behavioral reasoning theory and gender schema theory, the study explores the facilitators and inhibitors of mobile wallet adoption. Perceived usefulness, perceived ease of use, and trust prove to be important facilitators, while perceived risk and compatibility are important inhibitors.

In his study, Wasiq (2024) investigates the variables that impact Indian consumers' adoption of digital payments, namely mobile wallets. Ease of use, security, trust and social impact are combined using the UTAUT model.

The nearly ubiquitous proliferation of mobile wallets has fundamentally changed the global payments landscape by providing customers with a quick, easy, and digital way to manage transactions. However, despite their potential, mobile wallets have widely varying adoption worldwide, with serious opposition. This resistance can be categorized into three primary barriers: the value barrier, the risk barrier and the usage barrier.

A fuzzy mathematical model aligned with the PROMETHEE technique is employed to resolve and systematically fashionably assess these obstacles in this research. First, this mobile wallet adoption challenge decision-making model has been aimed at aggregating and integrating the value, risk, and usage barriers that have been introduced to this model to provide a comprehensive framework for this mobile wallet adoption in various markets.

Security, unstable technology infrastructure, complicated regulations, and low user uptake in the mobile wallet market are some of the challenges. For these problems, fuzzy models can better resolve traditional models' ambiguity, incomplete data, and unpredictability. Utilizing fuzzy logic and security, one can adaptively manage and authenticate using a defensive system, as that specific defensive system can adjust to the changing situational variable. It also offers device compatibility flexibility and management of inconsistent data in low connectivity areas. Both models are complex enough to handle cross-border transactions but can change depending on changing restrictions. Since they customize user experiences, they're more reliable and adaptable than rule-based systems or neural networks. They are more reliable and adaptable, and they encourage trust and adoption.

This paper employs the Fuzzy PROMETHEE MCDM method to assess the important barriers to mobile wallet adoption. The Fuzzy PROMETHEE approach for the integration of subjective expert opinions facilitates the prioritization of the various adoption barriers.

As to how these barriers can be assessed, fuzzy mathematical models are the innate models to manage subjectivity, ambiguity and uncertainty in the users' perceptions. To evaluate fuzzy numbers and linguistic terms related to the decision maker's perception in a fuzzy PROMETHEE method, the conventional PROMETHEE method is improved, which is then suited for mobile wallet F PROMETHEE. By incorporating fuzzy numbers or linguistic terms to represent judgment of decision makers, F-PROMETHEE extends the traditional PROMETHEE approach to be very suitable for evaluating barriers to mobile wallet adoption.

In the first step of the methodology, key barriers to adopting the mobile wallet would be found through a comprehensive literature review of the identified barriers to the adoption. Finally, a panel of mobile payment and fintech industry experts were assembled to subjectively assess these barriers' relative degree of importance. Therefore, this study applied the Fuzzy PROMETHEE method to the expert opinions to prioritize and sort the identified barriers.

Literature Review

Kapoor, Sindwani and Goel (2023) present a novel method for ranking and evaluating important criteria impacting the adoption of mobile wallets: The best-worst technique (BWM). Its seven essential acceptance criteria include 'policy and regulatory measures' while 'perceived security and trust' is most central. These conclusions are backed up by sensitivity analysis. For the first time, this study applies BWM to prioritize mobile wallet acceptability variables for service providers to apply to improve operations and increase adoption.

In Mahdiraji et al. (2018) represented triangular fuzzy COPRAS and Best Worst Method (BWM) techniques to identify, rank and evaluate the components of ecological sustainability in sustainable design. Sivagami et al.

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(2019) investigated applying a modified version of the COPRAS technique in the context of Probabilistic Linguistic Term Sets (PLTS) and used the technique to rank cloud providers. In order to evaluate and choose the most efficient m-wallet, Kumari and Mishra (2020) use the Intuitionistic fuzzy-based COPRAS model.

It is also mentioned in existing research on mobile wallet adoption that it faces several key barriers to adoption, including those of privacy and security as well as lack of perceived benefits over the current payment methods Eriksson et al. (2021). Those barriers that can prevent mobile wallet subscriptions include fragmented mobile payment options, lack of knowledge about functionality, old habits and the image of the service providers.

Determinants of mobile wallet adoption have also been addressed in mobile wallet adoption studies focusing on perceived risk, convenience offers and social influence (Cacas et al., 2022). Consumer behavior regarding mobile wallets is examined from the perspective of the Unified Theory of Acceptance and Use of Technology and the Diffusion of Innovation. For several years now, mobile wallets have become better known with the ease and the fact that their benefits apply (Rana et al., 2020).

PROMETHEE is a ranking and selection method from a finite set of alternative actions-taking criteria which are often inconsistent. PROMETHEE is a very straightforward ranking method, in both conception and through implementation, compared to other multi-criteria analysis methods (Brans et al., 1986). A discussion of straightforward, transparent, and reliable PROMETHEE methods for multi-criteria analysis is presented in this article. Two methodologies are examined: PROMETHEE I, which yields a partial ranking, and PROMETHEE II, which delivers a complete ranking. The methods are especially beneficial for those in positions of authority when assessing economic parameters. Furthermore, the stability of PROMETHEE rankings is analyzed in relation to those produced by the ELECTRE III method.

Through an extended PROMETHEE II approach, adequate consideration is given by which the specific difficulties involved with small and medium-sized enterprises can be overcome in order to select sustainable suppliers. Using this approach, which integrates subjective preferences with risk factors, we provide a comprehensive evaluation framework (Tong et al. 2021). Oubahman & Duleba (2021) applied PROMETHEE method in transportation planning. PROMETHEE offers partial and complete decision-making rankings but has not yet been applied to optimize public transportation. Future research could leverage the method to enhance service quality in public transport systems. However, as is the case for other digital wallets, their use has several advantages. However, the adoption rate of these mobile wallets is still very low and the technology has not been accepted widely (Madan and Yadav, 2016; Sharma et al., 2018; Leong et al., 2020; Singh et al., 2020). Consequently, an exhaustive investigation of the barriers to consumer adoption of mobile wallets has to be made. There is significant insecurity, a tendency for users to rely on cash and ease of use of traditional cards (Statista, 2018; Leong et al., 2020) as barriers that hinder the adoption of mobile wallets for financial transactions. To address this issue, this study employs the Fuzzy PROMETHEE approach, a multi-criteria decision-making technique, to comprehensively evaluate the key barriers to mobile wallet adoption from the perspective of industry experts. This in-depth analysis will aid in developing targeted strategies for over coming the identified challenges and increasing adoption of this new payment technology by mobile wallet service providers and policymakers. This paper provides an overview of the significant contributions in the literature related to the application of the PROMETHEE method in mobile wallet adoption.

Identification of Barriers to mobile wallet adoption

The adoption of mobile wallets is often hindered by several key barriers that prevent widespread usage. These barriers can be classified into the following categories:

Value barrier

The value barrier is the resistance to innovation because of the value of innovation from the consumer's point of view since a consumer will not change unless an innovation gives better value than the substitute (Ram and Sheth, 1989). It specifies that to entice users to change, innovative products must offer greater value than existing products (Chen and Kuo, 2017). With regard to m-wallet, if the users perceive low value of using m-wallet, then they will resist making transactions using it (Leong et al., 2020). Past studies in literature outlined that value barrier have a negative relationship with user intention related to various digitisation initiatives like online shopping (Lian and Yen, 2014), mobile banking (Laukkanen, 2016), mobile commerce (Moorthy et al., 2017), mobile payment solutions and intention to recommend mobile payment solutions (Kaur et al., 2020). Correspondingly, many studies reported a positive association between value barrier and user's resistance towards mobile banking (Yu and Chantatub, 2015), digital payment systems (Sivathanu, 2019), and m-wallet

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(Leong et al., 2020). Moorthy et al. (2017) investigated how usage barriers majorly impact innovation adoption. Supporting this, Cheng et al. (2018) found that usage barriers greatly affected customers' resistance to adopting e-wallet payment systems. It is found that the Value barrier positively influences the value barrier to Internet banking usage (Arif et al., 2020).

Usage barrier

Resistance to new products and innovations arises for one major reason—use barrier—if new products threaten to upset the status quo among consumers (Ram and Sheth, 1989). Usage barriers are the extent of how difficult a person can understand and use the technology (Anuar et al, 2020; Rombe et al., 2021). The Usage barrier (Laukkanen et al., 2008) is a key element influencing technological innovation and the usability. It is the unevenness because new ideas don't easily rub off on people's existing experiences and routines (Hew et al., 2019). On mobile wallets, transaction screens are smaller than on desktops and laptops; therefore, reading and typing text and graphics is quite difficult. But this makes evaluation and data entry a chore (Bruner and Kumar, 2005; Leong et al., 2020). An important variable because problems with use might decrease the chances of an innovation being widely used (Kaur et al., 2020). In previous research, we found a negative correlation between consumers' usage barrier and intentions to use mobile payment solutions, online shopping, mobile banking, mobile commerce, or their recommendations (Moorthy et al., 2017; Borraz-Mora et al., 2017; Gupta and Arora, 2017; Kaur et al., 2020). On the same vein, Yu and Chantatub (2015), Sivathanu (2019) and Leong et al. (2020) discovered that especially usage barriers were significantly correlated with the reluctance to use digital payment systems and m-wallets and mobile banking.

Risk barrier

The risk barrier refers to the level of risk associated with an innovation (Ram and Sheth, 1989). Perceived risk is an inherent part of innovation, as it is constantly associated with uncertainty (Laukkanen et al., 2008). Physical, functional, social, and economic type risks have been identified by Ram and Sheth (1989). Nevertheless, potential economic or financial risks retain consideration, such as threats to security (of virii and theft of information, including PIN numbers capable of resulting in unauthorized monetary transfers) (Leong et al., 2020). As a result, risk perception grew in line with the unpredictability of security technology, and consumer satisfaction was reduced (Tan et al., 2010; Arif et al., 2020). Functional risks emerge when individuals are concerned about the possibility of making careless errors while using mobile wallets (Leong et al., 2020). Similar preceding literature also reveals that risk barriers have a negative effect on user intentions and behaviors in a wide range of contexts, such as mobile banking (Laukkanen, 2016), online shopping (Lian et al., 2012; Lian and Yen, 2014), m-shopping (Gupta and Arora, 2017), mobile commerce (Moorthy et al., 2017) and mobile payment solutions (Kaur et al., 2020). Similarly, several investigations have backed the argument that risk barriers play a role in resistance to various digitized innovations, such as m-banking (Yu and Chantatub, 2015), digital payment systems (Sivathanu, 2019) and m-wallet (Leong et al., 2020).

It is necessary to address these challenges for mobile wallet adoption and user engagement and retention.

Research Methodology

The current study is descriptive research and aims to understand the ranking of the existing mobile wallet adoption barriers. To attain the objectives of this research paper, the researchers have selected three barriers –Risk Barrier, Usage barrier and Value barrier which are evaluated using Fuzzy MCDM method named PROMETHEE on the basis of linguistic variables through TrFNs. This was done by taking the assessments from the group of experts.

With the help of this mathematical model, the researchers have adopted an 11-step chronology of inter-related steps that aim to define the methodology adopted to assess the ranking of the selected mobile wallet adoption barriers.

Steps of the F-PROMETHEE Model

Step 1 –Deciding choices and variables - We have to decide the mobile wallet adoption barriers through some variables and some experts.

Step 2 –Deciding linguistic words - Decide linguistic words of variables as well as performance gratings of the choices.

Step 3 - Computing weights of the variables (w_j)-

$$w_j = \left(w_j^1, w_j^2, w_j^3, w_j^4\right) \quad (1)$$

$$w_j^1 = min(w_j^1) \quad (2)$$

$$w_j^2 = \frac{1}{k\left(\Sigma w_j^2\right)} \quad (3)$$

$$w_j^3 = \frac{1}{k\left(\Sigma w_j^3\right)} \quad (4)$$

$$w_j^4 = max(w_j^4) \quad (5)$$

Step 4 - Preparing a matrix – It is prepared as:

$$[F] = \left[x_{ij}\right]_{m*n} \quad (6)$$

where x_{ij} = fuzzy rating of the i^{th} option for the j^{th} variable, i= 1,2,…,m ; m is options, j= 1,2,…,n ; n be variable.

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Step 5 - Preparing combined matrix – It is prepared as:

$$\begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (7)$$

Where $x_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$are the ratings in TrFNs.

Where

$$a_{ij} = min(a_{ij}) \quad (8)$$

$$b_{ij} = \frac{1}{K}(\Sigma b_{ij}) \quad (9)$$

$$c_{ij} = \frac{1}{K}(\Sigma c_{ij}) \quad (10)$$

$$d_{ij} = \max(d_{ij}) \quad (11)$$

Step 6–Preparing a combined normalized matrix$[R]$- It is constructed as:

$$[R] = [r_{ij}] \quad (12)$$

For beneficial variable -

$$r_{ij} = \left(\frac{a_{ij}}{a_j^+}, \frac{b_{ij}}{a_j^+}, \frac{c_{ij}}{a_j^+}, \frac{d_{ij}}{a_j^+}\right) \quad (13)$$

Where

$$d_j^+ = \max(d_{ij}) \quad (14)$$

For non-beneficial variable-

$$r_{ij} = \left(\frac{a_j^-}{d_{ij}}, \frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad (15)$$

Where

$$a_j^- = mina_{ij} \quad (16)$$

Step 7 - Preparing a weighted-normalized matrix- It is prepared as:

$$V = [r_{ij} * w_j] \quad (17)$$

Step 8 - Building preference functions – Using Hamming distances to compare two given choices, say a and b on the basis of the variables, preference functions among the given alternatives are built. First, the maximum numeral (c) between the two fuzzy numerals is determined. Next, the Hamming distance is calculated, which is the sum of all the values determined by the absolute value of the difference between the maximum number and both the first and second alternatives. The following equations determine preference functions as analyzed by Hatami and Tavana (2011).

$V_{ac} \geq V_{bc}$, if and only if $d\{\max(V_{ac}, V_{bc}), V_{bc}\} \geq d\{\max(V_{ac}, V_{bc}), V_{ac}\}$ (18)

$V_{ac} < V_{bc}$, if and only if $d\{\max(V_{ac}, V_{bc}), V_{bc}\} < d\{\max(V_{ac}, V_{bc}), V_{ac}\}$ (19)

$P(a, b) = d\{\max(V_{ac}, V_{bc}), V_{ac}\}$ if $V_{ac} < V_{bc} and d\{\max(V_{ac}, V_{bc}), V_{bc}\}$ if $V_{ac} \geq V_{bc}$ (20)

Step 9 - Preparing fuzzy preference index – It is evaluated as:

$$\pi(a, b) = \Sigma\{w_j * P(a, b)\}/\Sigma w_j \quad (21)$$

Step 10 – Calculation of positive as well as negative flows - The TrFNs' defuzzification is calculated by adding up all 4 fuzzy integers and dividing the result by four. The TrFNs in rows as well as columns are defuzed to assess positive and negative flows, respectively.

Let x_A is the defuzzified value of the TrFNs A where $A = (a_1, a_2, a_3, a_4)$, then the defuzzification is calculated as:

$$x_A = \frac{a_1 + a_2 + a_3 + a_4}{4} \quad (22)$$

Step 11 – Finding net flows (NF')-It is calculated as:

$$NF' = PF - NF \quad (23)$$

Step 12 – Finding the ranking of options – It is analyzed as:

$$A^* = \{A_i ; \max(NF)\} \quad (24)$$

Results

Numerical Analysis

We have three experts, three mobile wallet adoption barriers i.e., Risk barrier, Usage barrier and Value barrier and three criteria based on sustainable mobile wallet adoption i.e., Accessibility, (A) Customer Satisfaction (CS) and Social image (SI).

The linguistic words for the weights of variables and performance ratings of the mobile wallet adoption barrier through TrFNs assessment by the experts are depicted in Table 1 and 2, respectively.

Table 1. Linguistic words are used to find the weights of the variables.

Linguistic words	TrFNs
Very low(VL)	(0.0,0.0,0.1,0.2)
Low(L)	(0.1, 0.2, 0.2, 0.3)
Medium low (ML)	(0.2, 0.3, 0.4, 0.5)
Medium (M)	(0.4, 0.5, 0.5, 0.6)
Medium high (MH)	(0.5, 0.6, 0.7, 0.8)
High (H)	(0.7, 0.8, 0.8, 0.9)
Very high (VH)	(0.8, 0.9, 1.0, 1.0)

Table 2. Linguistic words for ratings of the mobile wallet adoption barrier.

Linguistic words	TrFNs
Very poor(VP)	(0, 0, 1, 2)
Poor (P)	(1, 2, 2, 3)
Medium poor(MP)	(2, 3, 4, 5)
Fair (F)	(4, 5, 5, 6)
Medium good (MG)	(5, 6, 7, 8)
Good (G)	(7, 8, 8, 9)
Very good(VG)	(8, 9, 10, 10)

Table 3 shows the linguistic words for finding the weights of the variables

Table 3. Linguistic words for finding the weights of the variables.

	RB	UB	VB
E1	VH	M	H
E2	H	VH	H
E3	M	H	VH

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The linguistic words for determining the ratings of all the mobile wallet adoption barriers by all the experts are depicted in Tables 4.

Table 4. Linguistic words for the performance gratings of mobile wallet adoption barrier.

E1, E2, E3	A	CS	SI
RB	VG, G, G	MG, VG, VG	VG, MG, MG
UB	G, MG, MG	MG, G, G	G, VG, MG
VB	MG, VG, VG	G, MG, VG	VG, G, G

Fuzzy ratings for finding the weights of all the variables depicts Table 5.

Table 5. Fuzzy gratings are used to estimate the wts. of variables.

E1, E2, E3	A	CS	SI
RB	0.8,0.9,1,1	0.5,0.6,0.7,0.8	0.7,0.8,0.8,0.9
UB	0.7,0.8,0.8,0.9	0.8,0.9,1,1	0.7,0.8,0.8,0.9
VB	0.5,0.6,0.7,0.8	0.7,0.8,0.8,0.9	0.8,0.9,1,1

Finding the weights of each variable through equations (2)-(5) by Table 5. In Table 5, w_j^1 = min (0.8, 0.7, 0.5) = 0.5, w_j^2 = 1/3(0.9+0.8+0.6) = 0.7667, w_j^3 = 1/3(1, 0.8, 0.7) = 0.8333, w_j^4 = max (1, 0.9, 0.8) = 1. Table 6 depicts the weights of each variable.

Table 6. Criteria's weights using TrFNs.

Variable	Weights
A	(0.5, 0.7, 0.8, 1)
CS	(0.5, 0.7, 0.8, 1)
SI	(0.7, 0.8, 0.8, 1)

Preparing a matrix of mobile wallet adoption barriers for every criterion is shown by equation (6), which is depicted in Table 7.

Table 7. Matrix of mobile wallet adoption barrier.

	A	CS	SI
RB	(8,9,10,10), (7,8,8,9), (7,8,8,9)	(5,6,7,8), (8,9,10,910, (8,9,10,10)	(8,9,10,10), (5,6,7,8), (5,6,7,8)
UB	(7,8,8,9), (5,6,7,8), (5,6,7,8)	(5,6,7,8), (7,8,8,9), (7,8,8,9)	(7,8,8,9), (8,9,10,10), (5,6,7,8)
VB	(5,6,7,8), (8,9,10,10), (8,9,10,10)	(7,8,8,9), (5,6,7,8), (8,9,10,10)	(8,9,10,10), (7,8,8,9), (7,8,8,9)

Preparing a combined matrix represented by equation (7) through eqs (8)-(11) which depicts Table 8. Through Table 7, a_{ij} = min(8,7,7) = 7, b_{ij}= 1/3(9+8+8)=8.3, c_{ij} = 1/3(10,8,8)=8.7, d_{ij} =max(10,9,9)=10.

Table 8. Combined matrix of all the mobile wallet adoption barriers.

	A	CS	SI
RB	7,8.3,8.7,10	5,8,9,10	5,7,8,10
UB	5,6.7,7.3,9	5,7.3,7.7,9	5,7.7,8.3,10
VB	5,8,9,10	5,7.7,8.3,10	7,8.3,8.7,10

Preparing normalized matrix of mobile wallet adoption barrier represented by equation (12) through Table 8. For the beneficial variable, the first cell's value is computed by (7/10,8.3/10,8.7/10,10/10) = (0.7,0.84,0.88,1) by eq. (13) and (14) and for non-beneficial variables, it is computed as (5/10,5/8,5/7,5/5) = (0.5,0.63,0.72,1) by eq. (15) and (16) depicts Table 9.

Table 9. Normalized matrix of mobile wallet adoption barrier.

	A	CS	SI
RB	0.7,0.84,0.88,1	0.5,0.8,0.9,1	0.5,0.63,0.72,1
UB	0.5,0.68,0.74,0.9	0.5,0.74,0.78,0.9	0.5,0.61,0.63,1
VB	0.5,0.8,0.9,1	0.5,0.78,0.84,1	0.5,0.58,0.61,0.72

Preparing weighted normalized matrix as eq. (17) through Table 9, which depicts Table 10. Table 9 calculates the first cell as: (0.7*0.5+0.8*0.7+0.8*0.8+1*1)=(0.36,0.64,0.73,1).

Table 10. Weighted Normalized matrix of each mobile wallet adoption barrier.

	A	CS	SI
RB	0.36,0.64,0.73,1	0.26,0.62,0.73,1	0.36,0.52,0.6,1
UB	0.24,0.52,0.61,0.9	0.24,0.56,0.63,0.9	0.34,0.48,0.56,1
VB	0.26,0.62,0.75,1	0.26,0.58,0.68,1	0.34,0.48,0.53,1

Computing the preference function between mobile wallet adoption barriers RB and UB for A variable, which depicts Table 11 by eqs. (18)-(20) and Table 10.

Table 11. Preference function between mobile wallet adoption barrier RB and UB.

Alternative a	0.36	0.64	0.73	1.00
Alternative b	0.26	0.52	0.61	0.9
The max. numeral between a and b say c	0.36	0.64	0.73	1.00
Distance between a and c	0.00	0.00	0.00	0.00
distance between b and c	0.10	0.13	0.12	0.10

$d\{\max(V_{ac}, V_{bc}), V_{ac}\} = 0$ and $d\{\max(V_{ac}, V_{bc}), V_{bc}\}$ = 0.1+0.1227+0.1166+0.1= 0.4393 then

$V_{ac} \geq V_{bc}$ condition is true. So, the preference function is 0.4343. Preference functions among the entire mobile wallet adoption barrier for each variable are depicted in Table 12.

Table 12. Preference functions of each mobile wallet adoption barrier wrt each variable.

	A	CS	SI
P(RB,UB)	0.44	0.25	0.076
P(RB,VB)	0.13	0.082	0.138
P(UB,RB)	0.00	0.00	0.00
P(UB,VB)	0.35	0.19	0.06
P(VB,RB)	0.03	0.00	0.00
P(VB,UB)	0.00	0.00	0.00

Computing fuzzy preference index of mobile wallet adoption barriers RB and UB through eq. (21) and Table 12 as:

$\{w_j * P(a,b)\}$ =(0.5*0.44,0.7*0.44,0.8*0.44,1*0.44)= (0.22,0.34,0.35,0.44)

(0.5*0.262, 0.7667*0.262, 0.8333*0.262,1*0.262)= (0.131, 0.2008, 0.2183, 0.262)

(0.7*0.0774, 0.8333*0.0774,0.8667*0.0.774,1*0.0.774)= (0.0541,0.0644,0.0670,0.0774)

Now finding $\Sigma\{w_j * P(a,b)\}$=(0.2171+0.131+0.0541, 0.3329+0.2008+0.0644, 0.3619+ 0.2183+0.0670, 0.4343+0.262+0.0774) = (0.4022,0.5891,0.6472,0.7737).

Σw_j = (0.5+0.5+0.7,0.7667+0.7667+0.8333,0.8333+0.8333+0.8667,1+1+1)=(1.7,2.366,2.533,3)

Now finding $\Sigma\{w_j * P(a,b)\}/\Sigma w_j$ = (0.4022/3, 0.5891/2.5333, 0.6472/2.3667, 0.7737/1.7)= (0.1340,0.2325,0.2734,0.4551).

The fuzzy preference index of all mobile wallet adoption barriers is depicted in Table 13.

Table 13. Fuzzy preference index of all the mobile wallet adoption barriers.

	FPN1	FPN2	FPN3
FPN1	0,0,0,0	0.1341,0.2326, 0.2735,0.4552	0.067,0.1069,0.3797,0.2008
FPN2	0,0,0,0	0,0,0,0	0.2261,0.1776, 0.2056,0.3422
FPN3	0.0042,0.0076, 0.0009,0.0148	0,0,0,0	0,0,0,0

Computing the positive flows by defuzzification in rows through equation (22) in Table 13 i.e., (0.1341+0.067,0.2326+0.1069,0.2735+0.3797,0.4552+0.2008)/4=0.2988

Computing the negative flows by defuzzification in col. through equation (22) in Table 13 i.e., (0.0042+0.0076+0.0009+0.0148)/4=0.0068

Computing the net flows through eq. (23). Lastly, the ranking of the mobile wallet adoption barriers is found. The best barrier to mobile wallet adoption is computed through eq. (24). Table 14 depicts the positive, negative and net flows as well as the ranking of the barriers.

Table 14. Ranking of all the mobile wallet adoption barriers.

s	Positive flows	Negative flows	Net flows	Ranking
RB	0.2988	0.0068	0.293	1
UB	0.2378	0.2738	-0.037	2
VB	0.0068	0.4261	-0.4194	3

Hence, the Ranking of barriers to mobile wallet adoption - RB>UB>VB

Application of proposed methodology

This section discusses the application of F-PROMETHEE approach for prioritising barriers in the adoption of m-wallet. Three proposed barriers are considered for the purpose of analysis.

Data collection

After finalising the barriers to adopting m-wallet, the next step is to evaluate the importance and weight of the barriers using F-PROMETHEE. Four experts' opinions were gathered to evaluate the barriers: two academicians carrying out this research with doctorates in fields related to e-service adoption and two consumers with more than 12 years of experience who are regular users of various m-wallet applications.

Determination of the mobile wallet adoption barrier criterion

The best criteria represent the most important barrier chosen by experts that hinders the adoption of m-wallets among users, whereas the worst criteria are the ones that least hinder m-wallet adoption among users on the basis of the opinion of experts.

Discussion

Researchers have focused on the barriers to mobile wallet adoption among consumers utilizing FPROMETHEE. The findings indicate that the risk barrier is the primary challenge affecting consumer adoption of m-wallets. While this finding is in line with the earlier studies of risk barrier as one of the most striking blocking the path (Laukkanen et al., 2008; Arif et al., 2020). This can be explained by the reluctance of some customers to take the m-wallets, most of who are worried about how m-wallets can increase fraud and privacy issues. Sometimes, users may be charged beyond the amount to be paid, sometimes to the wrong vendor. The second most significant hurdle identified in adopting the mobile wallet is the usage barrier. Besides usage barrier, previous researchers have also flagged usage as a major barrier to their quest (Kuisma et al., 2007; Leong et al., 2020). Finally, it suggests that people might be unwilling to adopt m-wallets when keypads and displays prove small (Leong et al., 2020). The third challenge to

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the adoption of mobile wallets is the value barrier. If there are no perceived advantages to using mobile wallets over physical wallets, previous studies suggest that individuals are more likely to persist in using physical wallets. Through the Fuzzy PROMETHEE approach, these barriers were prioritized and provided significant insights to the practice of industry practitioners and policymakers. Addressing these critical barriers requires thoughtful solutions and interventions to raise the acceptance and use of mobile wallets to heights, resulting in a better, more secure payment environment.

Conclusion

The aim of the study was to identify and rank the inhibitors to m-wallet adoption. After thoroughly examining existing literature and consultations with specialists, the authors have identified three barriers to adopting mobile wallets. Expert evaluations were given regarding the inhibitors of m-wallets. It has used a new multi-criteria method called 'FPROMETHEE' to consolidate the ratings and facilitate bias in the prioritization of barriers. The inhibitors need to be prioritized in assessing their significance, which makes it easier to formulate strategies to address many of these inhibitors. As the major hurdle that must be faced to increase adoption rates for m-wallets among customers, we have identified the risk and value barriers, which follow closely behind. A step advance in the evaluation of such hurdles is the creative application of a fuzzy mathematical model, which provides a more sophisticated and flexible approach than conventional techniques. This study serves as a benchmark for guiding service providers in the m-wallet industry to overcome barriers to adoption and achieve a competitive advantage over their rivals.

Implication and future direction

The findings underscore the critical importance of risk barriers, usage barriers, and value in mobile wallet adoption. This has profoundly added to the industry and academia with the submission of a structure for prioritizing inhibitors of mobile adoption through FPROMETHEE.

Providing guidance for the management of the mobile wallet sector, the present investigation emphasizes the barriers to mobile wallet adoption. The results indicate that the actual highest barrier to consumer uptake of products on the market was the risk barrier. The risk barrier is important for existing and potential m-wallet service providers because if they do not ensure that users are well informed about the safety and security measures that m-wallet includes, it can be risky. This will increase their confidence in using mobile wallets. This means that if the Smartphone is stolen, its users will be protected by passwords and security codes. This implies that we need to have alerts and notices wherever transactions exceed a defined ceiling through a short messaging service. While mobile money is considered a key driver for use and perception of value in mobile wallets, several barriers to use and perceive mobile wallets need to be effectively managed to form a pool of customers. However, service providers must design easy and easy-to-understand applications to reduce usage barriers. It was found that the most appropriate way to obtain user feedback would be using surveys, and thereafter, improvements and upgrades would be instituted based on the findings. The additions are the way service providers treat the service interface graphics, design, input, output and structure (Hoehle and Venkatesh, 2015). Regarding the value barrier, we know that service providers may use television and print media to market the usage of m-wallet using social media and radio. And supporting more than one language in the app could also make the concept more generally acceptable. More innovative suggestions in these recommendations could potentially reduce the impact of the barriers to adopting m-wallets among consumers. Managers can use the findings to make a variety of policy decisions regarding means of increasing the user base. Consequently, results from the current study may serve as guidance for possible action to be undertaken for the members of the mobile industry as well as policy-makers regarding the smart move of completing the effective adoption of mobile wallets (Mustafo, 2013).

We rank order these barriers based on the Fuzzy PROMETHEE method to overcome barriers to mobile wallet adoption and making decision makers present order of priority to structure and systematically select and resolve the most crucial barriers to mobile wallet adoption. This could be the basis for the second part of this study: To see what implementation-specific strategies and interventions can be used to overcome these barriers and the potential of new developments like blockchain to increase the security and faith around the mobile wallet ecosystem.

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Conflict of Interest

The authors declare no conflict of interest.

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