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Ranking Mobile Wallet Service Providers Using Fuzzy Multi-Criteria Decision-Making Approach

Ashwarya Kapoor, J. C. Bose University of Science and Technology, YMCA, Faridabad, India
https://orcid.org/0000-0003-3858-3945

Rajiv Sindwani, J. C. Bose University of Science and Technology, YMCA, Faridabad, India
https://orcid.org/0000-0001-7457-6457

Manisha Goel, J. C. Bose University of Science and Technology, YMCA, Faridabad, India

ABSTRACT

The aim of this paper is to identify key dimensions of mobile wallet (m-wallet) service quality and to prioritize mobile wallet service providers on the basis of these dimensions. Based on extensive literature review and discussion with an expert, six key dimensions of m-wallet service quality, namely convenience, reliability and security, responsiveness, aesthetics, accessibility, and information quality/content, are proposed in this paper. Fuzzy TOPSIS approach is proposed to evaluate and rank mobile wallet alternatives. Four major mobile wallet players from the Indian market are prioritized on the basis of six key service quality dimensions. Examination of the literature indicates that this study is among the first attempts to identify m-wallet service quality dimensions as well as to prioritize mobile wallet alternatives using fuzzy TOPSIS. The findings will be valuable to academicians and practitioners alike. The key dimensions proposed in the paper will enlighten m-wallet service providers about the aspects of services to be focused on. Moreover, the fuzzy TOPSIS technique discussed in this paper will help m-wallet companies to compare them with their competitors. This will help managers to develop strategies to improve their services. On the academic front, the study will extend the knowledge base in the field of self-service technologies.

KEYWORDS

Experts, Fuzzy TOPSIS, Mobile Wallet Alternatives, Mobile Wallet Service Quality, Multi-Criteria Decision Making, Prioritization, Self-Service Technologies

INTRODUCTION

In the digital era, mobile phones have become an indispensable part of our lives. Approximately, worldwide there are a greater number of mobile phone users as compared to bank account holders (Madan & Yadav, 2016). Mobile communication technology has seen an amazing growth in the last ten years. Because of inconvenience and deficiency of conventional methods, mobile-technology based business solutions opened out (Kunganathan & Wikramanayake, 2014). Mobile wallet is among one such service initiative. It is a contemporary solution that enables customers to make electronic payment using mobile devices by entering pin code and touching smartphones on the payment terminal (Tang et al., 2014). Since m-wallet put forwards many benefits to users, it has the ability to replace

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other payment methods (Leavitt, 2012). In 2016, m-wallet transactions were valued at INR384bn (US$5.4bn). As users are switching to electronic mode of payments, the transaction worth is anticipated to be around INR100.6 trillion in 2024 (Global Data, 2020). There are many service providers offering mobile wallet services in India like Paytm, Mobikwik, PhonePe, Freecharge, Google Pay, etc. But users usually keep on switching among different alternatives of mobile wallet. Service providers must pay attention towards enhancing their quality of services offered since m-wallet service being an electronic form of service is distinct from other conventional services. Major difference is lack of physical contact between users and service providers (Agrawal et al., 2018). Additionally, users are now conscious about services and have less patience for substandard quality of services. As a consequence, service quality of m-wallet becomes a matter of foremost concern (Agrawal et al., 2018). Users have increased the utilization of m-wallet post demonetization and during pandemic Covid-19 (Kapoor et al., 2020). Service facilitators are battling against each other for capturing market share. Thus, dimensions impacting mobile wallet service quality require sincere attention. Key m-wallet service quality dimensions will assist service providers in increasing efficiency, gaining competitive edge and withholding customers (Routray et al., 2019).

Service quality dimensions of mobile wallets can act as a solid base for comparison among various m-wallet service providers. Measuring service quality is characterised by uncertainty, subjectivity and vagueness. The views of domain experts and users are not crisp, therefore, views should be depicted through fuzzy sets that hold the power to depict unclear data (Kahraman et al., 2007). Previously researchers have used several methods to rank criteria and alternatives in different areas but they lack adaptability/stability as their results get influenced easily. Therefore, service providers need an appropriate approach to make the decision. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique is amongst the widely utilized approaches in multi-criteria decision making. The key facet of this approach is that the best alternative has the shortest distance from the ideal solution and the farthest distance from the anti-idle solution. In the current framework, the environment is fuzzy and TOPSIS set up the ground for comparison of different m-wallets, Fuzzy TOPSIS technique appears to be the best choice for comparison of m-wallets. Fuzzy TOPSIS has been employed by many researchers in their studies (Awasthi et al., 2010). They have chosen to apply it in the manufacturing sector, and limited studies have applied it in the service sector. But there is hardly any study that used this approach to evaluate service providers in the area of electronic financial services like m-wallet. So, the application of Fuzzy TOPSIS fits well in the current case, aiming to contribute to mobile wallet service facilitators in enhancing their service quality and offering a base for their comparison.

This paper seeks to evaluate and prioritize mobile wallet alternatives based on dimensions of mobile wallet service quality using fuzzy TOPSIS. The objectives of this study are:

1. To review literature and propose key dimensions of mobile wallet service quality
2. To prioritize mobile wallet alternatives on the basis of proposed key mobile wallet service quality dimensions using fuzzy TOPSIS

Remaining paper is organised as follows. The subsequent section consists of an in-depth review of studies related to electronic service quality. Critical dimensions of m-wallet service quality are proposed in this section. Next, the paper discusses fuzzy TOPSIS methodology covering the various steps in fuzzy TOPSIS approach. The illustration section covers the numerical application of the proposed technique. Afterward, the conclusion and major contributions of the study are presented. Finally, limitations and future directions are discussed.

IDENTIFICATION OF MOBILE WALLET SERVICE QUALITY DIMENSIONS

Mobile wallet is a virtual wallet that facilitates instant payments and exchange transactions through smartphones (Singh et al., 2017). User either preload wallet with money through debit card, credit card or internet banking for making transactions or link the wallet with a bank account. Wallet to wallet transfer is also allowed by certain m-wallet service providers. It enables the users to keep track of their personal information, shopping details, banking information, payment history etc. (Singh et al., 2017). Globally, India is among the topmost markets with regard to m-wallet adoption, according to the estimates from Consumer Payments Insight Survey, 2017 (Global Data, 2018; Chawla & Joshi, 2019). As per Capgemini's World Payment Report (2017), the m-wallet industry in India is expected to expand to $4.4bn by 2022 along with an estimated compound annual growth rate (CAGR) of 148 percent over 5 years (Chawla & Joshi, 2019). Major driving forces that boost m-wallet usage include growing penetration of smartphones, utilization of new m-wallets, rising QR code installation among small and medium enterprises and government policies to encourage electronic payments. Global Data (2019) survey indicated that Indian users' usage of m-wallet (83.6%) is just after China (87%). M-wallet usage in India is more as compared to developed markets like UK and the US where users use cards primarily for making payments (Global Data, 2019). Mobile wallet usage enhanced immensely post demonetisation and Covid-19 in India. It has given rise to tough competition among mobile wallet service providers. Thus, service quality becomes the major determinant in differentiating services offered by service providers from one another and building competitive advantage.

To identify service quality dimensions of mobile wallets, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines of Moher et al. (2009) were followed. The ultimate objective of PRISMA is to report literature review in a clear and transparent manner. It has been used in various fields like health, technology and environment (Hughes-Morley et al., 2015). Based on these guidelines, authors consulted Google Scholar for systematic review of literature. Relevant keywords were used for assessing the pertinent studies. The initial search revealed that various themes have been touched upon by researchers related to m-wallets but there is scarcely any study that is directly associated with service quality of mobile wallets. This shows that m-wallet service quality is in nascent stage. As mobile wallet is a form of electronic service, so, to identify dimensions of mobile wallet service quality, researchers took into consideration the research work on service quality of electronic financial services like internet banking, mobile banking and ATM banking. Thus, various combinations of keywords related to electronic financial services were used to extract papers. Search resulted in 332 relevant articles. Total 197 articles comprising book chapters, conference papers and articles in language other than English were removed. Next, 135 titles and abstracts were reviewed by authors. 68 articles where service quality was not the major theme were excluded. Afterward, the detailed examination of 67 full text of shortlisted studies was conducted by researchers for their quality assessment based on the problem statement, research design, data collection, data analysis and conclusion. It helped in analysing their rigorousness, credibility and relevance. Finally, 22 articles qualifying assessment criteria were taken into consideration for extensive analysis. On the basis of review of studies on electronic financial services quality, it is found that various scales and several dimensions were proposed by researchers to measure e-service quality across the globe. Various service quality dimensions were discussed at length with an academician who is doing research on service quality from the last decade and also uses different m-wallets regularly. Dimensions that are both relevant and critical in the context of mobile wallets are considered. Based on systematic literature review and interaction with expert academician, authors propose six key dimensions to measure m-wallet service quality. The proposed key dimensions are described in Table 1.

These dimensions are briefed below

Table 1. Proposed m-wallet dimensions of service quality

S.No.	Dimensions	Authors and Year
1.	Convenience/Ease of use	Ladhari (2010),Zavareh, Ariff, Jusoh, Zakuan, Bahari and Ashourian (2012), **Sindwani and Goel (2014), Roy and Balaji, (2015), Jun and Palacios (2016), Sindwani and Goel (2016),** Ahmad and Khan (2017), **Agrawal, Tripathi and Agrawal (2018), Huang, Luo and Wang (2019), Taherdoost (2019)**
2.	Reliability & Security	Shin (2009), **Ladhari (2010),** Fu Tsang, Lai and Law (2010), **Rocha (2012),** Ha and Stoel (2012), Shaw (2015), Sindwani and Goel (2015a), Jun and Palacios (2016), **Ahmad and Khan (2017),** Rahman, Ahmad and Khan (2017), Agrawal, Tripathi and Agrawal (2018), Huang, Luo and Wang (2019), Taherdoost (2019)
3.	Responsiveness	Ladhari (2010), **Fu Tsang, Lai and Law (2010)**, **Sindwani and Goel (2015 b), Jun and Palacios (2016), Agrawal, Tripathi and Agrawal (2018), Huang, Luo and Wang (2019),** Aslam, Tariq and Arif (2019), **Taherdoost (2019)**
4.	Aesthetics	Zavareh, Ariff, Jusoh, Zakuan, Bahari and Ashourian (2012), **Jun and Palacios (2016), Agrawal, Tripathi and Agrawal (2018), Taherdoost (2019)**
5.	Accessibility	Loonam and O'loughlin (2008), Rocha (2012), **Jun and Palacios (2016), Huang, Luo and Wang (2019),** Aslam, Tariq and Arif (2019), **Taherdoost (2019)**
6.	Information Quality/Content	Loonam and O'loughlin (2008), Ladhari (2010), Kao and Lin (2016), **Jun and Palacios (2016), Ahmad and Khan (2017), Taherdoost (2019)**

Source: The authors

CONVENIENCE/EASE OF USE

Convenience deals with user's comfort, effortlessness and simplicity of work utilizing m-wallet. It is one of the key factors which customers consider while choosing among different mobile wallet alternatives. This dimension facilitates the customers in easily finding what they need and allows clear navigation to the customers (Agrawal et al., 2018). According to Huang et al. (2019), online customer services focusing on ease of use should provide customers with straightforward operation and an understandable interface for contents. An easy to understand interface like easy login and navigation helps in retaining existing customers and building a new customer base (Jun & Palacios, 2016).

Reliability and Security

Reliability is related to accurate technical operation of m-wallet services and facilitating precise services regularly. (Huang et al., 2019). Security refers to the extent to which m-wallets are secure from intrusion (Parasuraman et al., 2005; Sarmah & Sarma, 2011). Reliability is an essential dimension in ascertaining behaviour of consumers in context of online environment (Ahmad & Khan, 2017). When it comes to transacting online, security is must to build trust among customers since there is no physical contact between customer and employee (Huang et al., 2019). Shin (2009) associated security with the extent to which consumer think that utilizing a distinct mobile payment system is safe.

Responsiveness

Responsiveness is associated with rapid response in case of difficulty or query related to m-wallet (Parasuraman et al., 2005; Parida & Baksi, 2011). It is the willingness to assist customers and enhancing the level of service. It covers aspects like providing timely services, notifying customers the precise service time and providing services to meet customer's demand. Customers usually seek online support services when they face difficulty. The speed of response of service providers towards customer's problems highly affects the service quality. The faster the response of service providers, more will be the satisfaction perceived by the customers (Sindwani, 2020).

Aesthetics

Aesthetics refers to the appearance and attractiveness of m-wallet application. It is linked with looks and feel of the application. Jun & Palacios (2016) in their study revealed "Aesthetics" as one of the crucial dimensions of mobile based banking application quality. Zavareh et al. (2012) found it as one of the important dimensions in accessing the internet banking services quality in Iran. Experts stressed the importance of this dimension in context of m-wallets.

Accessibility

Accessibility refers to the degree to which m-wallet provide access in form of buttons, links, menu etc. to solve customer problems during pre-transaction, transaction and post-transaction (Huang et al., 2019). Loonam & O'Loughlin, (2008) stressed the importance of accessibility in e-banking domain. Huang et al. (2019) outlined a positive association between accessibility and perceived service quality of online customer services.

Information Quality/Content

It is related to the degree to which m-wallet provides customers with relevant, accurate and up-to-date information (Kao & Lin, 2016). Quality information increases user's perception of electronic services capabilities (Pai & Huang 2011). Therefore, the information offered should be error-free, precise and pertinent (Cao et al., 2005). It affects satisfaction level of the customers. Service providers should have the potential to provide customized information through their websites. Key factors deciding information quality/content include presentation style, precision, completeness and recent information (Lin, 2007).

FUZZY TOPSIS METHODOLOGY

Multi-Criteria Decision Making (MCDM) is explained as the method of picking out the finest alternative among the available alternatives on the basis of criterion affecting the performance of the alternatives (Stanujkic et al., 2013). Several MCDM techniques have been used by researchers for evaluating services. Büyüközkan & Çifçi (2012) applied combined fuzzy TOPSIS and fuzzy AHP to evaluate e-service quality in the healthcare industry. To improve and enhance e-store business, Chiu et al. (2013) used DANP with VIKOR. Najafi et al. (2015) examined service quality in the hospitality industry by using data envelopment analysis (DEA). Shayganmehr & Montazer (2020) applied PROMETHEE and AHP for appraising e-services of websites in Iranian universities.

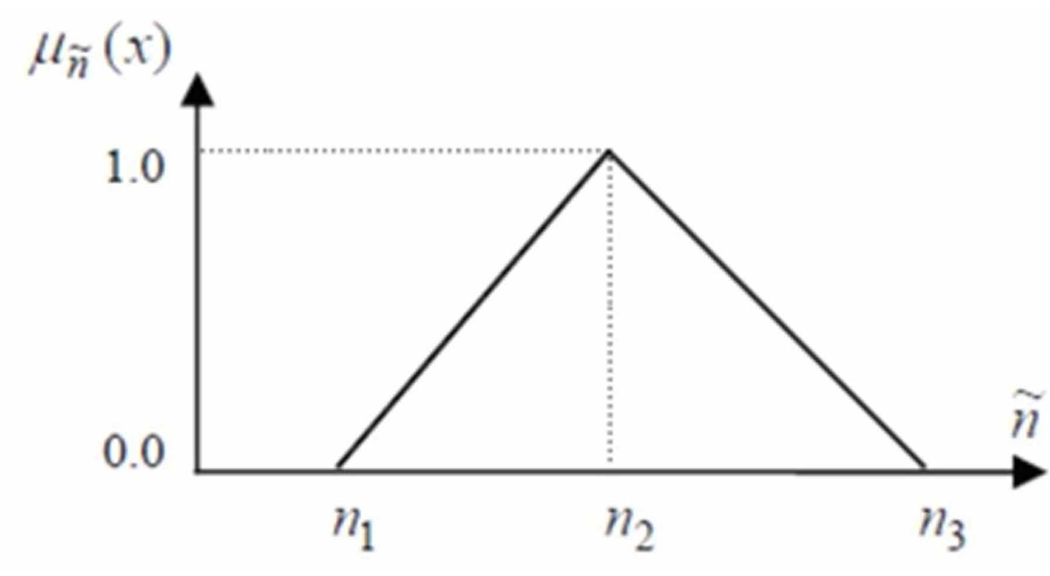
To find solution to MCDM problems, Hwang and Yoon (1981) proposed TOPSIS method. TOPSIS utilise different scalar values for the best and the worst alternatives concurrently. It is straightforward to implement in comparison to another prevailing technique (Kim et al., 1997). For small number of alternatives and criteria, AHP method is believed to be appropriate since it makes the use of pairwise comparison. On the other hand, TOPSIS is appropriate while handling large alternatives and criteria. Additionally, results derived from TOPSIS have minimal impact whenever an alternative is included or eliminated. These advantages make TOPSIS robust technique in contrast to other techniques. Ratings and weights are taken in crisp numbers under the conventional TOPSIS method. As human judgments are vague and cannot be ascertained by exact numeric values, crisp numbers are not appropriate in depicting actual world situation. To get over this issue, Zadeh (1965) developed the fuzzy set theory. It handles variability and ambiguity of human judgments. Taking into account the benefits of fuzzy systems, researchers integrated fuzzy logic with TOPSIS. Fuzzy TOPSIS is more advance to TOPSIS explicitly for the problem underhand (Gupta et al., 2018). It has been used in different domains involving electronic services. In the field of electronic services fuzzy TOPSIS is employed to resolve issues in the area of e-commerce such as shopping websites' competitive advantages (Sun & Lin, 2009), ranking of B2C electronic commerce websites in context of e-alliance (Yu et al., 2011) and electronic commerce website (Kang et al, 2016). M-wallet service differs from above mentioned services. M-wallet service is an extension of e-banking service, enabling users to store their personal information like debit cards, credit cards, vouchers etc. Literature did not focus much on evaluating m-wallet service quality and its service providers. Thus, in the present study, authors utilized fuzzy TOPSIS to rank m-wallet service providers based on proposed m-wallet service quality dimensions.

The Membership Function of the Triangular Fuzzy Number

Triangular fuzzy numbers (TFN) are utilized to assess the decision maker's preference. Triangular fuzzy numbers are employed as they are simple to compute and easy to understand (Pedrycz, 1994). Triangular fuzzy numbers are exhibited as a triplet (n_1, n_2, n_3), where $n_1 \leq n_2 \leq n_3$. The parameters n_1, n_2, and n_3 specify the smallest possible value, the most promising value, and the largest possible value respectively that depict a fuzzy event. Some of the relevant notations and properties of fuzzy numbers are explained below (Zadeh, 1965; Awasthi et al., 2010). The membership function of the fuzzy number ñ is represented in Figure 1.

The membership function of the triangular fuzzy number is given as

Figure 1. Triangular fuzzy number ñ



$$\mu_{\tilde{n}}(x) = \begin{cases} 0, & x < n_1, \\ \dfrac{x - n_1}{n_2 - n_1}, & n_1 \leq x \leq n_2, \\ \dfrac{x - n_3}{n_2 - n_3}, & n_2 \leq x \leq n_3, \\ 0, & x > n_3 \end{cases} \tag{1}$$

Let $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$ be two triangular fuzzy numbers. Then the operations of triangular fuzzy numbers are defined as

Addition of two triangular fuzzy numbers

$$\tilde{m} + \tilde{n} = (m_1, m_2, m_3) + (n_1, n_2, n_3) = (m_1 + n_1, m_2 + n_2, m_3 + n_3)$$

Multiplication of two triangular fuzzy numbers

$$\tilde{m} \text{ x } \tilde{n} = (m_1, m_2, m_3) \text{ x } (n_1, n_2, n_3) = (m_{1.}\, n_1, m_{2.}\, n_2, m_{3.}\, n_3)$$

The distance between fuzzy numbers is computed through vertex method (Chen, 2000) as:

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]}$$

Linguistic variable set

An appropriate set of linguistic variable set may assist decision makers to make the right judgment. Fuzzy set theory utilizes conversion scales to convert the linguistic terms into fuzzy numbers. In present study, a scale of 1–9 has been utilized to rate the criteria and alternatives. The linguistic variables and fuzzy ratings utilized for the criteria and alternatives are exhibited in Tables 2 and 3 respectively (Awasthi et al., 2010).

The steps of fuzzy TOPSIS method are proposed as follows

Step 1: Allocation of ratings to the criteria and the alternatives

Table 2. Linguistic variables to define the criteria rating

Linguistic variable	Membership function
Very Low (VL)	(1,1,3)
Low (L)	(1,3,5)
Medium (M)	(3,5,7)
High (H)	(5,7,9)
Very High (VH)	(7,9,9)

Source: Awasthi et al. (2010)

Table 3. Linguistic variable to define the ratings of alternative

Linguistic variable	Membership function
Very Poor (VP)	(1,1,3)
Poor (P)	(1,3,5)
Fair (F)	(3,5,7)
Good (G)	(5,7,9)
Very Good (VG)	(7,9,9)

Source: Awasthi et al. (2010)

Assume m is a set of criteria, where $C = \{C1, C2, C_3, . . ., Cm\}$ and the criteria weights are represented by wi ($i = 1,2,3, . . ., m$), n is a set of alternatives, where $A = \{A1, A2, A3, . . ., A_n\}$, and k is a set of decision makers, where D={$D1$, $D2$, $D3$, ... Dk}

The values of alternatives are to be evaluated against criteria. The performance assignment of each decision maker for each alterative with respect to each criterion is represents by R̃k with membership function μR̃k(x)

Step 2: Compute the aggregate fuzzy ratings for the criteria and the alternatives.

Let the fuzzy ratings of all decision-makers be triangular fuzzy numbers R̃ = (ak, bk, ck), k=1,2,3,...K. In this case aggregate fuzzy rating can be described as

R̃ = (a,b,c) where

$$a = \min_k \left\{a_k\right\}, b = \frac{1}{K}\sum_{k=1}^{K} b_k, c = \max_k \left\{c_k\right\}$$

Let the fuzzy rating and importance weight of the kth decision maker be x̃ijk= (aijk, bijk, cijk) and wijk= (wjk1, wjk2, wjk3), i = 1,2,3, ...m, j = 1,2,3,.......n respectively. Then the aggregated fuzzy ratings (x̃ij) of alternatives regarding each criteria are represented by x̃ij = (aij,bij, cij) where

$$a_{ij} = \min_k \left\{a_{ijk}\right\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ijk}, c_{ij} = \max_k \left\{c_{ijk}\right\} \quad (2)$$

The aggregated fuzzy weights (w̃ij) for each criterion are computed as w̃j = (wj1, wj2, wj3) where

$$w_{j1} = \min_k \left\{w_{jk1}\right\}, w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}, w_{j3} = \max_k \left\{c_{jk3}\right\} \quad (3)$$

Step 3: Determination of fuzzy decision matrix

The fuzzy decision matrix with respect to all alternatives and the criteria is created as follows:

$$\widetilde{D} = \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{12} \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} \cdots & \tilde{x}_{2n} \\ \vdots & \vdots \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{mn} \end{pmatrix}, \quad (4)$$

$$\widetilde{w} = \left[\widetilde{w}_1, \widetilde{w}_2, \widetilde{w}_3, \cdots \widetilde{w}_n\right] \quad (5)$$

Where x̃ij = (aij, bij, cij) and w̃j = (wj1, wj2, wj3); i = 1,2,3,....m; j = 1,2,3,...n

Step 4: Normalization of fuzzy decision matrix

Normalization is essential for converting the raw data into normalized data to bring the various criteria scales into a comparable scale. The normalized fuzzy decision matrix R̃ is given by

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn} \text{ where} \tag{6}$$

For benefit criteria

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right), \; c_j^* = \max_i c_{ij} \tag{7}$$

For cost criteria

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right), \; a_j^- = \min_i a_{ij} \tag{8}$$

Step 5: Determination of the weighted normalized matrix

On the basis of importance assigned to each criteria, the weighted normalized fuzzy decision matrix Ṽ is calculated by multiplication the weights of evaluation criteria with the normalized fuzzy decision matrix

$$\tilde{v}_{ij} = \left[\tilde{v}_{ij} \right]_{mxn} \quad i = 1, 2, 3.....,m \; j = 1,2,3,.....,n \tag{9}$$

Where,

$$\tilde{v}_{ij} = \tilde{r}_{ij} \left(. \right) \tilde{w}_j$$

Step 6: Determination of fuzzy negative ideal solution and fuzzy positive ideal solution

Calculation of fuzzy positive ideal solution (FPIS, A^*) and fuzzy negative ideal solution (FNIS, A^-) of the alternatives are given by:

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^* \cdots\cdots\cdots \tilde{v}_n^* \right) \tag{10}$$

$$A^{-} = \left(\tilde{v}_1^{-}, \tilde{v}_2^{-} \cdots\cdots\cdots \tilde{v}_n^{-}\right) \tag{11}$$

where

$$\tilde{v}_j^{*} = \max_i \left\{v_{ij3}\right\}$$

$$\tilde{v}_j^{-} = \min_i \left\{v_{ij1}\right\}$$

i= 1, 2, 3,....,m , j = 1, 2, 3,.....,n

Step 7: Computation of the distance of each alternative from FPIS and FNIS

The distance of each weighted alternative from the FPIS and the FNIS is given by:

$$d_i^{*} = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^{*}\right),\ i = 1, 2, 3, \cdots, m \tag{12}$$

$$d_i^{-} = \sum_{j=1}^{n} d_v\left(\tilde{v}_{ij}, \tilde{v}_j^{-}\right),\ i = 1, 2, 3, \cdots, m \tag{13}$$

where d_v (...) represent the distance measurement of distance between two fuzzy numbers.

Step 8: Computation of the closeness coefficient (C_i) of each alternative and rank the alternatives

The closeness coefficient C_i shows the distances to the fuzzy positive ideal solution (A*) and the fuzzy negative ideal solution (A^-) concurrently. The closeness coefficient of each alternative is given by

$$C_i = \frac{d_i^{-}}{d_i^{*} + d_i^{-}}, i = 1, 2, 3, \ldots\ldots\ldots, m \tag{14}$$

Considering the value of closeness coefficient (CC_i) the different alternatives are ranked in decreasing order. The best alternative is and nearest to the FPIS and a far from the FNIS.

Illustration

To exemplify the methodology, 4 major mobile wallet players from the Indian market are considered. Authors have shortlisted these m-wallet alternatives based on their popularity. The names of mobile wallet service providers are not disclosed in the paper because of confidentiality. These alternatives have been represented as A, B, C and D. These alternatives were evaluated along 6 m-wallet service quality criteria i.e. convenience, reliability and security, responsiveness, aesthetics, accessibility and

Table 4. Linguistic rating of criteria

Criteria	Decision Makers		
	D1	D2	D3
Convenience(C1)	H	VH	VH
Reliability and security(C2)	VH	H	VH
Responsiveness (C3)	H	M	M
Aesthetics(C4)	L	H	M
Accessibility(C5)	M	H	H
Information quality/content(C6)	VH	H	H

Source: The authors

information quality/content as proposed in the literature review section. Alternatives were evaluated by 3 decision makers D1, D2 and D3 (1 academician having doctorate in service quality, 1 senior banker having substantial knowledge of mobile wallet operations and 1 customer who is a heavy user of various mobile wallet applications) having an average experience of more than 12 years. Decision makers provided linguistic ratings to criteria and various alternatives for each criterion utilizing Table 2 and Table 3 respectively. These ratings have been described in Table 4 and Table 5.

Further, Aggregate fuzzy weights ($\tilde{w}_j$) have been calculated for each criteria by making use of Equation (3). For instance, aggregate fuzzy weights for criteria C1 is given by $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$$W_{j1} = \min_k(5,7,7), W_{j2} = \frac{1}{3}\sum_{k=1}^{3}(7+9+9), W_{j3} = \max_k(9,9,9)$$

Table 5. Linguistic rating of alternatives

Criteria	A			B			C			D		
	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Convenience (C1)	G	F	G	VG	G	VG	F	F	P	F	G	G
Reliability and security (C2)	VG	VG	G	VG	G	VG	F	G	G	G	G	VG
Responsiveness (C3)	G	F	F	F	VG	G	P	VP	P	VP	P	P
Aesthetics (C4)	G	VG	G	G	VG	F	G	F	G	VG	G	G
Accessibility (C5)	F	G	G	G	F	G	G	G	G	G	F	G
Information quality/content (C6)	VG	G	G	G	VG	F	G	VG	G	F	F	G

Source: The authors

Table 6. Aggregate fuzzy weight for criteria

Criteria	Decision Makers			Aggregate Fuzzy Weight
	D1	D2	D3	
Convenience (C1)	(5,7,9)	(7,9,9)	(7,9,9)	(5,8.33,9)
Reliability and security (C2)	(7,9,9)	(5,7,9)	(7,9,9)	(5,8.33,9)
Responsiveness (C3)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5.67,9)
Aesthetics (C4)	(1,3,5)	(5,7,9)	(3,5,7)	(1,5,9)
Accessibility (C5)	(3,5,7)	(5,7,9)	(5,7,9)	(3,6.33,9)
Information quality/ content (C6)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7.67, 9)

Source: The authors

$$\tilde{w}_j = (5, 8.33, 9)$$

In addition, aggregate fuzzy weights for rest of the criteria have been determined. It has been shown in Table 6.

Then, aggregate fuzzy weights have been calculated for alternatives by utilizing Equation (2). For instance, aggregate fuzzy weight for alternative A for criteria C1 is stated as

$$a_{ij} = \min_k (5,3,5), b_{ij} = \frac{1}{3}\sum_{k=1}^{3}(7+5+7), c_{ij} = \max_k (9,7,9)$$
$$= (3, 6.33, 9)\text{‘}$$

Likewise, aggregate fuzzy weights for A, B, C and D have been computed along 6 criteria C1, C2, C3, C4, C5 and C6. It has been expressed in Table 7.

Next, fuzzy decision matrix of alternatives has been normalised by utilizing Equation (6-8). For instance, normalized rating for alternative A along criteria C1 is as follows

$$C_j^* = \max_i (9,9,7,9) = 9$$
$$a_j^- = \min_i (3,5,1,3) = 1$$

Since C1 is a benefit (B) category criteria,

$$\tilde{r}_{ij} = \left(\frac{3}{9}, \frac{6.33}{9}, \frac{9}{9}\right)$$
$$= (0.33, 0.70, 1)$$

Table 7. Aggregate fuzzy weight for alternatives

Criteria	A				B				C				D			
	D1	D2	D3	Aggregate	D1	D2	D3	Aggregate	D1	D2	D3	Aggregate	D1	D2	D3	Aggregate
Convenience (C1)	(5,7,9)	(3,5,7)	(5,7,9)	(3,6.33,9)	(7,9,9)	(5,7,9)	(7,9,9)	(5,8.33,9)	(3,5,7)	(3,5,7)	(1,3,5)	(1,4.33,7)	(3,5,7)	(5,7,9)	(5,7,9)	(3,6.33,9)
Reliability and security (C2)	(7,9,9)	(7,9,9)	(5,7,9)	(5,8.33,9)	(7,9,9)	(5,7,9)	(7,9,9)	(5,8.33,9)	(3,5,7)	(5,7,9)	(5,7,9)	(3,6.33,9)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7.67, 9)
Responsiveness (C3)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5.67,9)	(3,5,7)	(7,9,9)	(5,7,9)	(3,7,9)	(1,3,5)	(1,1,3)	(1,3,5)	(1,2.33,5)	(1,1,3)	(1,3,5)	(1,3,5)	(1,2.33,5)
Aesthetics (C4)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7.67,9)	(5,7,9)	(7,9,9)	(3,5,7)	(3,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(3,6.33,9)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7.67,9)
Accessibility (C5)	(3,5,7)	(5,7,9)	(5,7,9)	(3,6.33,9)	(5,7,9)	(3,5,7)	(5,7,9)	(3,6.33,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(3,6.33,9)
Information quality/ content (C6)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7.67,9)	(5,7,9)	(7,9,9)	(3,5,7)	(3,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7.67, 9)	(3,5,7)	(3,5,7)	(5,7,9)	(3, 5.67,9)

Source: The authors

Table 8. Normalized fuzzy decision matrix for alternatives

Criteria	Alternatives			
	A	B	C	D
Convenience (C1)	(0.33,0.70,1)	(0.56,0.93,1)	(0.11,0.48,0.78)	(0.33,0.70,1)
Reliability and security (C2)	(0.56,0.93,1)	(0.56,0.93,1)	(0.33,0.70,1)	(0.56,0.85,1)
Responsiveness (C3)	(0.33,0.63,1)	(0.33,0.78,1)	(0.11,0.26,0.56)	(0.11,0.26,0.56)
Aesthetics (C4)	(0.56,0.85,1)	(0.33,0.78,1)	(0.33,0.70,1)	(0.56,0.85,1)
Accessibility (C5)	(0.33,0.70,1)	(0.33,0.70,1)	(0.56,0.78,1)	(0.33,0.70,1)
Information quality/ content (C6)	(0.56,0.85,1)	(0.33,0.78,1)	(0.56,0.85,1)	(0.33,0.63,1)

Source: The authors

Similarly, all the normalized values for alternatives A. B, C and D for all 6 criteria have been calculated. It has been shown in Table 8.

Further, a fuzzy weighted decision matrix has been put up by using Equation (9). $\tilde{w}_i$ values from Table 6 and $\tilde{r}_{ij}$ values from Table 8 have been employed to determine the fuzzy weighted decision matrix for alternatives. For instance, for alternative A, fuzzy weight for criteria C1 is calculated as follows:

$$\tilde{v}_{ij} = (0.33,0.70,1) * (5,8.33,9) = (1.65,5.83,9)$$

Likewise, fuzzy weights of all 4 alternatives have been calculated for all 6 criteria in Table 9. The fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) have been computed by utilizing Equation (10) and Equation (11) for alternatives A, B, C and D. For instance, for criteria C1 $(A^-) = (0.55, 0.55, 0.55)$ and $(A^*) = (9, 9, 9)$. Likewise, it has been calculated for all 6 criteria. It has been presented in Table 9.

Then, distance $d_v(.)$ have been computed for all alternatives from fuzzy positive ideal matrix (A^*) and fuzzy negative ideal matrix (A^-) by utilizing Equation (12) and Equation (13). For instance, for alternative A and criteria C1, distances have been calculated and given by.

$$d_v(A_1, A^*) = \sqrt{\frac{1}{3}\left[(1.65-9)^2 + (5.83-9)^2 + (9-9)^2\right]} = 4.62$$
$$d_v(A_1, A^-) = \sqrt{\frac{1}{3}\left[(1.65-0.55)^2 + (5.83-0.55)^2 + (9-0.55)^2\right]} = 5.79$$

Similarly, distances have been computed for remaining criteria of all alternatives. Results have been shown in Table 10.

In next step, distances d_i^- and d_i^+ have been calculated by using Equation (12) and Equation (13). For instance, for alterative A and criteria C1, distances d_i^- and d_i^+ are as follows:

Table 9. Weighted Normalized fuzzy decision matrix for alternatives, FNIS and FPIS

Criteria	Alternatives				FNIS(A-)	FPIS(A*)
	A	B	C	D		
Convenience (C1)	(1.65,5.83,9)	(2.8,7.75,9)	(0.55,4,7.02)	(1.65,5.83,9)	0.55	9
Reliability and security (C2)	(2.8,7.75,9)	(2.8,7.75,9)	(1.65,5.83,9)	(2.8,7.08,9)	1.65	9
Responsiveness (C3)	(0.99,3.57,9)	(0.99,4.42,9)	(0.33,1.47,5.04)	(0.33,1.47,5.04)	0.33	9
Aesthetics (C4)	(0.56,4.25,9)	(0.33,3.9,9)	(0.33,3.5,9)	(0.56,4.25,9)	0.33	9
Accessibility (C5)	(0.99,4.43,9)	(0.99,4.43,9)	(1.68,4.94,9)	(0.99,4.43,9)	0.99	9
Information quality/content (C6)	(2.8,6.52,9)	(1.65,5.98,9)	(2.8,6.52,9)	(1.65,4.83,9)	1.65	9

Source: The authors

Table 10. Distance $d_v(A_i,A^-)$ and $d_v(A_i,A^*)$for alternatives

Criteria	$d_v(A_i,A^-)$				$d_v(A_i,A^*)$			
	A	B	C	D	A	B	C	D
Convenience (C1)	5.79	6.54	4.23	5.79	4.62	3.65	5.78	4.62
Reliability and security (C2)	5.55	5.55	4.88	5.32	3.65	3.65	4.62	3.75
Responsiveness (C3)	5.36	5.55	2.80	2.80	5.59	5.33	7.01	7.01
Aesthetics (C4)	5.50	5.41	5.33	5.50	5.59	5.81	5.93	5.59
Accessibility (C5)	5.03	5.03	5.17	5.03	5.32	5.32	4.83	5.32
Information quality/content (C6)	5.13	4.93	5.13	4.62	3.86	4.59	3.86	4.88
$\sum$	32.36	33.01	27.54	29.06	28.63	28.35	32.03	31.17

Source: The authors

$$d_i^- = \sqrt{\frac{1}{3}\left[\left(1.65-0.55\right)^2+\left(5.83-0.55\right)^2+\left(9-0.55\right)^2\right]}+\sqrt{\frac{1}{3}\left[\left(2.8-1.65\right)^2+\left(7.75-1.65\right)^2+\left(9-1.65\right)^2\right]}+ \sqrt{\frac{1}{3}\left[\left(2.8-1.65\right)^2+\left(6.52-1.65\right)^2+\left(9-1.65\right)^2\right]}=32.36$$

$$d_i^+ = \sqrt{\frac{1}{3}\left[\left(1.65-9\right)^2+\left(5.83-9\right)^2+\left(9-9\right)^2\right]}+\sqrt{\frac{1}{3}\left[\left(2.8-9\right)^2+\left(7.75-9\right)^2+\left(9-9\right)^2\right]}+ \sqrt{\frac{1}{3}\left[\left(2.8-9\right)^2+\left(6.52-9\right)^2+\left(9-9\right)^2\right]}=28.63$$

Then, the closeness coefficient (CC_i) has been calculated using Equation (14) for all alternatives. For example, closeness coefficient for alternative A is given by

Table 11. Closeness coefficient for the three alternatives

	Alternatives			
	A	B	C	D
d_i^-	32.36	33.01	27.54	29.06
d_i^+	28.63	28.35	32.03	31.17
CC_i	0.53	0.54	0.46	0.48
Rank	2	1	4	3

Source: The authors

$$C_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1, 2, 3, ..., m$$

$= 32.36/(32.36+28.63) = 0.53$

Similarly, closeness coefficient has been calculated for the remaining three alternatives. Results have been presented in Table 11.

By looking at closeness coefficient in Table 11, it can be inferred that B>A>D>C. This indicates that m-wallet service provider B is best according to the opinion of decision makers.

CONCLUSION AND CONTRIBUTION

In present study, authors used fuzzy TOPSIS technique for comparing mobile wallet alternatives based on service quality dimensions. Authors have proposed a framework to assess 4 mobile wallets based on 6 key dimensions. The proposed technique is comprised of 2 steps. In the first step, authors have proposed 6 key dimensions to measure service quality in the context of mobile wallets namely convenience, reliability and security, responsiveness, aesthetics, accessibility and information quality/content based on systematic review of literature and interaction with an expert. In the second step, linguistic ratings have been provided by decision makers to selected criteria and alternatives. Fuzzy TOPSIS has been applied to aggregate the ratings and thereby prioritizing alternatives. 4 mobile wallet service providers have been ranked based on their scores.

This research remarkably contributes to the academics and industry by figuring out major dimensions of mobile wallet service quality. Additionally, it provides a framework to evaluate and rank mobile wallet service providers on the basis of service quality dimensions using fuzzy TOPSIS. Extensive literature review revealed that this is one of the contemporary studies to identify service quality dimensions in the context of mobile wallet and to rank mobile wallet alternatives utilizing fuzzy TOPSIS. Mobile wallet providers should focus on proposed service quality dimensions to get through and compete in the rapidly changing environment. For ensuring convenience, service providers should make the m-wallet application easy to operate and user-friendly. To enhance reliability and security, service providers should combine fingerprints, PIN etc. for verifying users' authentication. Responsiveness could be improved by offering real-time online service facilities to customers. Service providers must respond to the users' queries timely. Customers normally prefer a well-designed app with an attractive appearance. Therefore, service providers should improve menu design and layout enabling users to easily access the various services facilitated by m-wallet. For upgrading information quality, service provider should offer the latest and precise information to customers regarding transactions and payment history.

From academician perspective, these 6 key dimensions open a new direction to get insight into this area and conduct future research. The fuzzy TOPSIS technique used in this paper will assist mobile wallet service providers to compare them with their competitors in the field. Managers might utilize the findings in framing policies for improvement of quality. Finally, the study offers a direction for refining the effectiveness of mobile wallet business, gaining competitive advantage and hence increasing profits.

Limitations and Further Study

As service quality of mobile wallets is in the emergent stage, so, further research could be carried out to validate dimensions of service quality considered in present study. More than 4 mobile wallet service providers can be compared using the same approach in future research. The m-wallet service providers have been evaluated and ranked on the basis of the opinion of 3 decision makers. Opinion of the larger number of decision makers may be taken. The decision maker's psychological behaviours which are crucial factors were not taken into consideration in the proposed method. Fuzzy TOPSIS provides priority ranking but cannot define the association between variables. In the future, DEMATEL might be utilized to establish the association between variables. Other multi-criteria decision making techniques could be utilized in future research and findings using those methods might be compared with this research finding.

Conflicts of Interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Corresponding Author:

Correspondence should be addressed to Ashwarya Kapoor; ashwaryakapoor@yahoo.com

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Ashwarya Kapoor received her bachelor's and master's degree from University of Delhi. Currently, she is pursuing PhD from J.C. Bose University of Science and Technology, YMCA, Faridabad, India. Her research interest is management of financial services. She has presented many papers in international conferences.

Rajiv Sindwani holds PhD degree in management. He is working as assistant professor at J. C. Bose University of Science and Technology, YMCA, Faridabad, India. He is having total 15 years of experience in various sectors including consumer durables, banking, and education. He has many published papers in national and international journals.

Manisha Goel (PhD) is working as Associate professor at J.C. Bose University of Science and Technology, YMCA with more than 20 years of teaching experience. She has presented more than 20 papers in national and international conferences. She has got more than 50 research articles published in international journals.