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A Model for Developing a Mobile Payment Service Framework

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Abstract: The rise of wireless communication has spurred the global adoption of mobile payment services, a trend that is significantly reducing the use of cash. This shift, driven by new technologies and lifestyle changes, not only presents opportunities for businesses but also enhances consumers' daily activities. Consumers' and businesses' willingness to adopt mobile payment services has increased due to factors such as easier access to new technologies, convenience, changing lifestyle choices, and economic conditions. Despite challenges such as limited access to technology, security concerns, and high transaction fees, the potential benefits of mobile payment services are promising. Therefore, this research aims to construct a suitable model for developing a mobile payment service framework that both consumers and businesses are willing to adopt. The proposed model integrates the Delphi method, interpretive structural modeling (ISM), quality function deployment (QFD), an analytic network process (ANP), and fuzzy set theory. To demonstrate the practical application of the model, a case study of developing a mobile payment service framework is presented, showcasing how the model can be used to address real-world challenges and enhance the adoption of mobile payment services. The case study results show that ease of use, system and service quality, and reliability are the most important customer requirements, and encryption, edge computing, authentication, and interoperability are the most important engineering characteristics.

Keywords: mobile payment service; interpretive structural modeling; quality function deployment; analytic network process; fuzzy set theory

MSC: 90-11

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1. Introduction

Mobile payment, often called m-payment, involves using a mobile device to initiate, authorize, and confirm financial transactions, extending beyond retail purchases to include services such as bill payments and electronic funds transfers [1,2]. Conceptually, mobile payment represents a new form of value transfer leveraging advanced mobile phone features and tokenization for secure transactions [3]. Mobile payment methods can be categorized into remote and proximate systems. Remote payments involve online transactions, and proximity payments facilitate in-person purchases through methods like quick-response (QR) code scanning or near-field communication (NFC) [4].

Mobile payment has experienced remarkable growth in recent years, driven by the rise of mobile commerce and online e-commerce [5]. In Western markets, where card-centric ecosystems dominate, original equipment manufacturer payment services like Apple Pay and Google Pay maintain a strong presence due to the prior prevalence of card payments [5]. Conversely, mobile wallets are progressively replacing cash-based payment methods in regions where payment card usage is not as widespread [5]. This surge is evident with the emergence of various digital mobile payment products such as PayPal, Apple Pay, Google Pay, Samsung Pay, WeChat, and Paytm. These solutions offer convenience, adaptability, and efficiency, catering to both physical and virtual transactions facilitated 21e electronic or internet-connected devices.

The implementation of mobile payment services involves numerous stakeholders, such as consumers, issuers, merchants, acquirers, mobile network operators, mobile device manufacturers, financial services firms, software and technology providers, and the government [6,7]. Consumers utilize mobile payment devices, while issuers provide capabilities and manage transactions [7]. Merchants accept mobile payments, facilitated by acquirers who provide intermediary services [7]. Mobile network operators ensure connectivity, while device manufacturers integrate payment technology [7]. Financial services firms offer additional solutions, and software providers develop necessary applications [7]. Government regulators oversee compliance and security. Collaboration among these stakeholders has enabled the successful introduction and operation of mobile payment tools, driving innovation and improving the efficiency of financial transactions.

The rapid evolution of mobile technologies has transformed consumer behavior, offering time-saving benefits, economic advantages, versatility, and traceable transactions [8]. Consumers benefit from the convenience of carrying fewer physical payment instruments and the improved security of mobile transactions. In response to the COVID-19 pandemic, consumer behavior has shifted dramatically, with a notable rise in the adoption of digital mobile payments [9]. Necessity has driven this surge to maintain social distancing and reduce physical contact, as traditional payment methods like cash are perceived as potential carriers of the virus. Governments and international health organizations have advocated for contactless payment methods to curb transmission, leading to a rapid increase in their usage [8]. Consequently, mobile payment transactions have become essential in epidemic-prevention efforts [5]. This trend reflects a broader societal shift towards embracing alternative payment mechanisms to minimize physical interaction with currency. As the pandemic continues to shape daily life, the need for contactless transactions is likely to persist, further solidifying the role of digital mobile payments in the post-COVID-19 world.

The potential of mobile payment as an alternative payment mode has garnered global attention, particularly as consumers increasingly rely on mobile devices for daily activities. For example, businesses can increase sales as a result of convenience, reduce cash-handling costs, streamline checkout processes, enhance customer experiences, improve security through encryption, access valuable customer data for targeted marketing, accept payments anytime and anywhere, and integrate their systems with loyalty programs to retain customers [10,11]. In addition, mobile payment services can be adapted to various business sizes and industries, and they can streamline accounting processes, reduce the risk of counterfeit currency, and facilitate international transactions. Overall, adopting mobile payment options can modernize operations, increase efficiency, drive business growth, and enhance competitiveness. As mobile payment systems continue to evolve, with the advantages obtained by both consumers and businesses, they are poised to play a central role in shaping the future of commerce and transactions worldwide.

As mobile payment is flourishing, good mobile payment systems and services are crucial for both consumers and businesses. The adoption of mobile payment tools is influenced by multiple factors that interact in complex ways. Understanding these factors through various theoretical frameworks can provide a deeper understanding of the behavior and intentions of both consumers and businesses. This has been researched abundantly in the past, utilizing theoretical models such as the technology acceptance model (TAM), unified theory of acceptance and use of technology (UTAUT), theory of planned behavior (TPB), and diffusion of innovations (DOI). However, no research has been published on how to develop a suitable framework to provide mobile payment services that both consumers and businesses are willing to adopt, which is the purpose of this study. A structured mobile payment service framework is essential for secure, efficient, and user-friendly mobile payments. Consumers want simplicity, convenience, and intuitive interfaces. Ensuring privacy and protecting transaction data using strong security protocols is critical to building trust. In addition, data breaches compromise sensitive data and erode trust, underscoring the importance of data protection for merchants. Therefore, service providers must implement security, fraud protection, and compliance strategies to reduce risk. Effective mobile payment systems require strong encryption and authentication to prevent unauthorized access and fraud, ensuring transaction accuracy and increasing consumer and merchant confidence in digital transactions. Thus, this paper introduces a model for developing a mobile payment service framework and showcases how the model can be used to address real-world challenges and enhance the adoption of mobile payment services. The rest of this paper is organized as follows. Section 2 reviews the current adoption of mobile payment services from the perspectives of consumers and of merchants and some related works on mobile payment services. Section 3 reviews the methodologies applied in the proposed model. Section 4 constructs a model for developing a mobile payment service framework, integrating the Delphi method, interpretive structural modeling (ISM), quality function deployment (QFD), analytic network process (ANP), and fuzzy set theory. Section 5 applies the model to a case study. Some conclusions are made in Section 6.

2. Literature Review

2.1. Consumers' Adoption of Mobile Payment Services

The adoption of mobile payment tools is a complex process, influenced by multiple factors. To better understand these factors, insights provided by various theoretical frameworks must be considered. Some theoretical frameworks that have been employed to understand mobile payment adoption include the technology acceptance model (TAM), unified theory of acceptance and use of technology (UTAUT), theory of planned behavior (TPB), and diffusion of innovations (DOI) theory [2,5,9,12,13]. The TAM and UTAUT have been widely applied to understand mobile payment adoption, and these models emphasize the importance of perceived ease of use, perceived usefulness, subjective norms, and attitude in shaping users' intentions [2,14]. Additionally, DOI complements TAM by focusing on attributes, such as perceived technology security and intention to recommend the technology, that influence consumer behaviors [10].

The perceived ease of use and perceived usefulness of mobile payment applications play crucial roles in adoption decisions [2,9,12,14,15]. Consumers seek convenience and simplicity in mobile payment solutions. Developers should prioritize user-friendly interfaces and communicate the benefits of their systems effectively to potential users. Studies have also highlighted the importance of perceived trust and perceived risk in influencing users' intentions to adopt mobile payment services [2,9,12,15]. Consumers need assurance that their privacy is safeguarded and their transactional data remain secure, highlighting the necessity for robust security protocols in mobile payment systems [11]. Service providers must address these concerns by implementing strategies to reduce risk and enhance trust, such as developing seals of security guaranteeing the protocols used, offering guarantees against fraud and ensuring compliance with service conditions [15]. Furthermore, compatibility with existing habits and technologies, perceived security of the technology, performance expectations, and social influence are significant determinants of adoption and intention to recommend mobile payment services [9,10,12,13]. Marketing efforts should focus on highlighting these factors to convince target markets, utilizing channels like social media and customer testimonials [15]. Studies have also examined the impact of consumer attitudes on continued usage of mobile payment services [16]. Factors such as openness to change and resistance to mobile payments influence users' willingness to continue using these services. Addressing these attitudes through targeted interventions can help sustain adoption rates [16].

Overall, the literature suggests that a combination of factors, including usefulness, ease of use, trust, system and service quality, enjoyment, compatibility, technology security, social influence, innovativeness, cost, payment habits, mobile self-efficacy, and technological self-efficacy, shapes users' intentions to adopt and continue using mobile payment services [2,5,9,10,12–17]. Service providers and developers must address these factors to enhance adoption rates and ensure the long-term success of mobile payment systems. Through understanding the underlying drivers of consumer behavior and leveraging appropriate theoretical frameworks, stakeholders can develop strategies to promote the widespread adoption of mobile payment services.

2.2. Merchants' Adoption of Mobile Payment Services

Most of the literature has focused on consumer perspectives; however, merchants' roles in mobile payment services are equally crucial in the widespread adoption of mobile payment technologies [4,11,18]. Merchants face barriers stemming from limited resources, concerns over costs, and apprehensions regarding the adoption of technologies [11]. Small retailers may even worry about sales taxes or income taxes, since these taxes may not be present when no invoice is issued. On the other hand, merchants expect mobile payments to offer potential operational advantages over paper money, checks, and credit cards, as comparative risk, clearing, and settlement costs can be replaced with cheaper operating costs [6].

Security and trust emerge as paramount considerations not only for consumers but also for merchants. Breaches in security jeopardize sensitive transactional data and erode trust in the payment system and the merchants facilitating it [4,11]. Merchants must prioritize data protection to ensure consumer confidence and mitigate the risks associated with digital transactions [11]. On the other hand, merchants may also be concerned about transaction success and ensuring that the payments they receive are correct and unaffected by fraud. Therefore, good mobile payment systems must employ robust encryption and authentication measures to prevent unauthorized access and fraud.

Compatibility with existing systems represents another significant concern for merchants. Merchants often rely on point-of-sale (POS) systems and backend infrastructure to manage transactions and inventories [6]. Integrating mobile payment solutions with existing POS and customer relationship management (CRM) systems can be complex and costly [11]. Concerns arise for merchants regarding potential disruptions to operational efficiency and that the risk of system incompatibility may lead to potential loss of revenue. Thus, service providers and developers must consider the compatibility of mobile payment solutions with merchants' existing infrastructures to minimize disruptions and ensure a smooth transition.

Implementing mobile payment technologies incurs upfront hardware, software, and training costs. Additionally, merchants are subject to transaction fees or subscription charges imposed by mobile payment service providers [6]. Balancing the potential benefits of mobile payments, such as increased sales and improved customer experience, against these costs is a key consideration for merchants, especially small businesses with limited budgets [11]. To be competitive against other service providers, a service provider needs to consider the various costs and fees charged to the merchants when developing the mobile payment platform.

Usability emerges as a critical factor influencing merchants' adoption of mobile payment technologies. Merchants require intuitive and efficient payment processes that minimize transaction times and reduce friction at the checkout, and the usability and reliability of mobile payment solutions directly impact both the merchant and the customer experience [6,11]. A seamless user experience enhances customer satisfaction and encourages repeat business. Thus, merchants may be hesitant to adopt mobile payment systems if they perceive customer demand to be low or that customers are resistant to change or if they themselves have concerns about system reliability. Service providers and developers must provide user-friendly interfaces and intuitive payment processes to achieve streamlined, hassle-free transaction processes. The systems need to demonstrate tangible improvements in operational efficiency, both at the front end (payment processing) and back end (accounting reconciliation), to justify their adoption by merchants [11].

The maintenance and troubleshooting of mobile payment systems require technical expertise and support. Merchants rely on service providers to promptly resolve issues and ensure system uptime. Concerns about the availability of reliable technical support and the responsiveness of service providers may influence merchants' decisions to adopt and choose mobile payment technologies [11]. Therefore, service providers must develop a stable and reliable system and provide a prompt service for problem solving. In summary, to alleviate merchants' concerns, service providers need to offer secure, cost-effective, and user-friendly mobile payment solutions, along with robust technical support and educational resources.

2.3. Related Works on Mobile Payment Services

Some frameworks and models have been developed to study mobile payment services, and most of these have been related to consumers' adoption of the services. Some recent works are reviewed here. Oliveira et al. [10] identified the main determinants of mobile payment adoption and intention to recommend the technology. A research model was constructed that integrated the extended unified theory of acceptance and use of technology (UTAUT2) and the innovation characteristics of diffusion of innovations (DOI) with perceived security and intention to recommend the technology. Data were further analyzed using structured equation modeling (SEM). Fang et al. [9] proposed a hybrid, data-driven causality exploration method for exploring the key factors affecting mobile payment usage intention. The SEM was first applied to distinguish the direct effects between indicators, and the DEMATEL was adopted to determine the interdependence among the variables and their causes and effects. The key factors affecting mobile payment usage intention were identified. Fu et al. [11] studied the critical factors affecting the introduction of mobile payment tools by microretailers. An ANP and the Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR) were integrated to identify the critical factors that influenced microretailers' introduction of mobile payment tools. Jegerson and Hussain [5] identified the acceptance factors for the digital mobile payment market in the United Arab Emirates (UAE) by implementing an AHP framework based on the adoption factors selected from the unified theory of acceptance and use of technology (UTAUT) and the information systems (IS) success model. The importance of the criteria and sub-criteria were prioritized. P. H. [2] studied customers' adoption of mobile payment services for the application of an emerging financial technology. Structural equations were analyzed to determine the direct effects of variables on the adoption of mobile payment services, and indirect effects were studied using a mediation test. The analysis helped explain the impact of adoption readiness, trust, and intention to use digital payments. Zhang et al. [17] studied the factors determining consumers' acceptance of adopting near-field communication mobile payment from a developing country's viewpoint. An extended model of mobile technology acceptance was constructed based on the mobile technology acceptance model (MTAM), self-efficacy theory, critical mass theory, flow theory, and system and service quality to explain behavioral intention.

To summarize, past works generally utilized theoretical models such as the TAM, UTAUT, TPB, DOI, and ANP, and most aimed to study consumers' behaviors. However, to the authors' knowledge, no research has been published on developing a suitable framework to provide mobile payment services that both consumers and merchants are willing to adopt. In addition, this work is the first to transform consumers' and merchants' requirements into engineering characteristics for developing the mobile payment service framework.

3. Research Methods

3.1. Fuzzy Delphi Method (FDM)

The Delphi method has been widely used to promote convergence of expert feedback after several rounds. However, this method has some disadvantages, one of which is the number of rounds required to complete the process. Another is experts' uncertainty in their assessments. Introducing fuzzy set theory into the Delphi method can solve these problems. The steps of the fuzzy Delphi method (FDM) for selecting key influencing factors in this study are as follows [19–24]:

Step 1. Collect all possible influencing factors;
Step 2. Collect the importance of each factor from each expert;
Step 3. Calculate the minimum, geometric mean, and maximum values of the most conservative cognition value and of the most optimistic cognition value for each factor;
Step 4. Calculate the triangular fuzzy numbers for the most conservative cognition value and the most optimistic cognition value for each factor;
Step 5. Examine experts' opinions for consensus;
Step 6. Select key influencing factors.

3.2. Interpretive Structural Modeling (ISM)

Interpretive structural modeling (ISM), developed by Warfield in the 1970s [25–27], is a methodology designed to enhance understanding of complex situations and formulate action plans to address problems. ISM enables individuals or groups to create a visual representation of the intricate relationships among elements within a complex system and to construct a binary matrix, known as the adjacency matrix, that depicts these relationships [28]. The core concept of the ISM involves utilizing the practical experience and knowledge of experts to break a complicated system down into smaller subsystems or elements, which are then used to build a multilevel structural model [25,26].

The ISM process includes the following steps [25,26,29]:

Step 1. Identify and list the elements that constitute the complex system;
Step 2. Establish a relation matrix that shows the contextual relationships among the factors;
Step 3. Develop a reachability matrix and check for transitivity;
Step 4. Use the reachability matrix to create a multilevel structural model that illustrates the hierarchy and interactions among the elements.

3.3. Quality Function Deployment (QFD)

Quality function deployment (QFD) is a systematic approach to understanding and meeting customer requirements in order to improve product or service quality effectively. Initially developed by Yoji Akao and Shigeru Mizuno, QFD facilitates the translation of customer needs into quality specifications using a tool called the house of quality (HOQ) [30,31]. This method encompasses four phases, including product planning, part deployment, process planning, and production planning, all interconnected to ensure a comprehensive approach to quality enhancement throughout the development cycle [31,32]. The HOQ matrix, resembling a house, is a pivotal analytical tool in QFD implementation, and each phase has its own distinct HOQ. In the first phase, that of product planning, the HOQ captures customer requirements (CRs), engineering characteristics (ECs), and their interrelationships and identifies gaps between customer perceptions and business objectives [31]. The HOQ matrix functions as a navigation map by systematically representing these elements, guiding marketing and product planning decisions with customer needs at the forefront.

Researchers have widely acknowledged the benefits of QFD in reducing design time and costs while enhancing product and service quality [30]. QFD has evolved into a versatile design approach that is applicable across various industries. It facilitates the timely launch of new products, fosters cost efficiencies, and elevates overall quality standards by systematically integrating customer requirements into the design and production processes [30]. In addition, QFD can be an open innovation approach that leverages external resources such as customer feedback, supplier insights, and stakeholder contributions [31]. It enables companies to create products, services, or business models that align closely with market demands and current industrial conditions.

The first HOQ contained seven steps, as follows [33–35]:

Step 1. Obtain customer requirements (CRs);
Step 2. Develop engineering characteristics (ECs);
Step 3. Establish the relationship between CRs and ECs;
Step 4. Complete competitive surveys and calculate the relative importance of CRs;
Step 5. Conduct competitive technical benchmarking;

Step 6. Determine the relationships among ECs;
Step 7. Calculate the importance of ECs.

3.4. Analytic Network Process (ANP)

The analytic network process (ANP) developed by Saaty is an extension of the analytic hierarchy process (AHP) [36]. It is a multi-criteria decision-support methodology that decomposes a complex problem into a network structure [20,36]. The process for the ANP is outlined as follows [20]:

Step 1. Break down the complex problem into a network of interrelated elements;
Step 2. Develop a questionnaire based on the constructed network and have experts complete it;
Step 3. Develop pairwise comparison matrices based on the results of the questionnaire;
Step 4. Calculate the maximum eigenvalues and eigenvectors;
Step 5. Ensure the consistency of the pairwise comparison matrices;
Step 6. Develop an unweighted supermatrix;
Step 7. Adjust the unweighted supermatrix to form a weighted supermatrix;
Step 8. Compute the limit supermatrix to derive the priority weights of the alternatives.

For the details of the steps for each of the above methodologies, readers can refer to FDM [19–24], ISM [25,26,29], QFD [33–35], and ANP [20].

4. Proposed Model

This paper proposes an integrated model for developing a mobile payment service framework. Although QFD is a popular new product development method, it has some shortcomings in practice. To account for the imprecision and ambiguity of human judgment and information, in the proposed model, fuzzy set theory has been applied. Due to limited resources, only some CRs and ECs could be considered, and the FDM was applied to extract important CRs and ECs. In order to understand whether CRs had an impact on ECs, and whether there were interrelationships among CRs and among ECs, the ISM was used next. The results were then used to build a FANP-QFD model. Then, the FANP-QFD model was used to calculate the priority of ECs. The proposed framework is presented in Figure 1, and the steps are described in detail as follows.

Step 1. The problem of developing a mobile payment service framework was defined.

Phase 1: Fuzzy Delphi method (FDM) [24,35];

Step 2. A committee of experts in the mobile payment service industry was formed, comprising managers in sales, R&D, operations, engineering, etc.
Step 3. Possible CRs and ECs were listed. Based on the information collected and experts' opinions, possible CRs and ECs in the mobile payment service framework were generated. A questionnaire was prepared to evaluate the importance of CRs (ECs), and experts were invited to fill out the questionnaire. The importance of CR (EC) i evaluated by expert k is $S_i^k = \left(C_i^k, O_i^k\right), i = 1, 2, \ldots N$ with $1 \leq C_i^k \leq 10$ and $1 \leq O_i^k \leq 10$, where C_i^k is the most conservative cognition value and O_i^k is the most optimistic cognition value.
Step 4. The perceived importance of each CR (EC) was collected from each expert. After calculating C_i, the geometric mean of C_i^k from all experts, C_i^k values that were outside two standard deviations were eliminated.
Step 5. The minimum value, the geometric mean, and the maximum value of the most conservative cognition value and of the most optimistic cognition value were computed for each CR (EC). The minimum C_i^l, the geometric mean C_i^m, and the maximum C_i^u of C_i^k were computed. In addition, the minimum O_i^l, the geometric mean O_i^m, and the maximum O_i^u of O_i^k were computed.

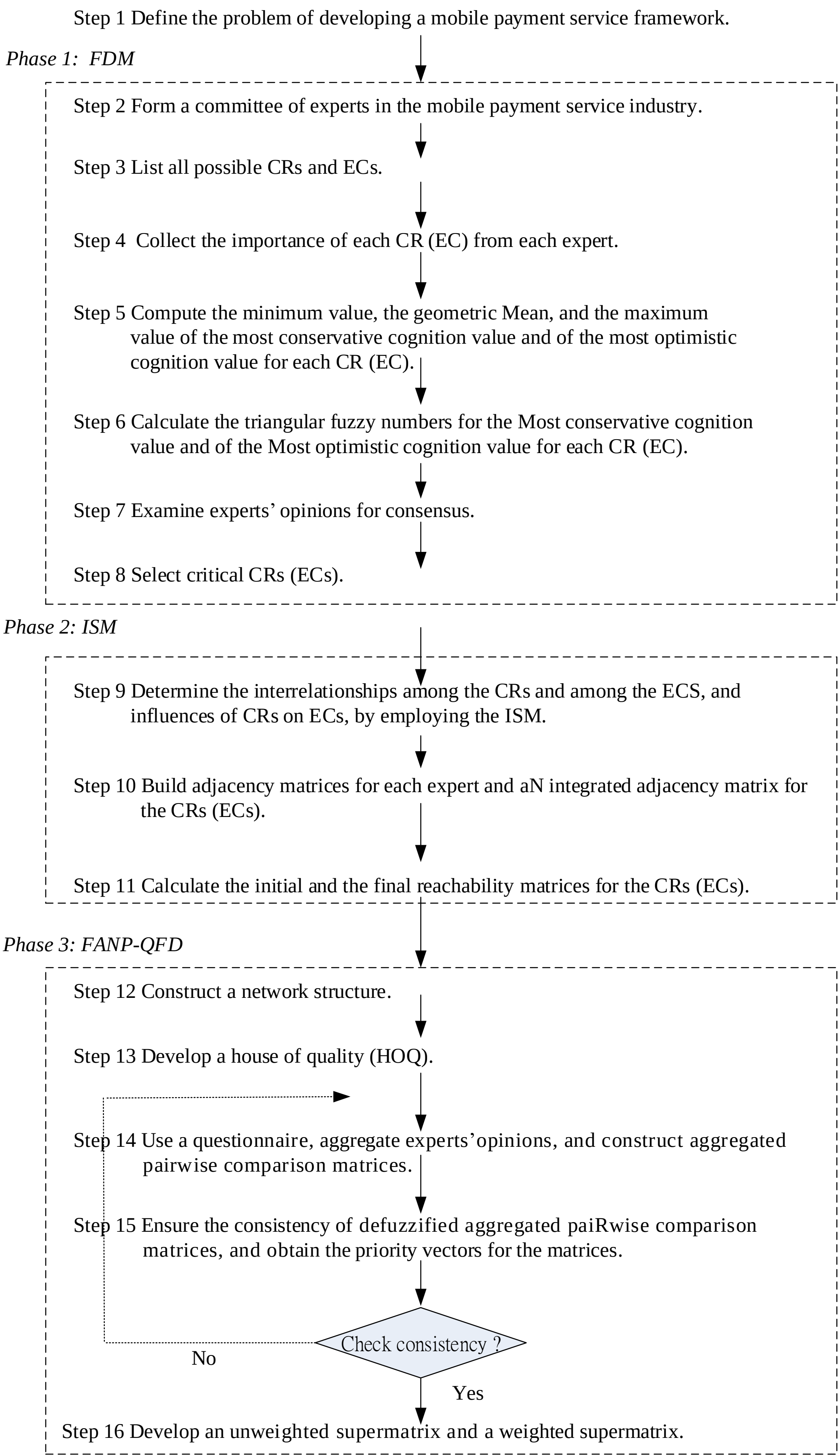

Figure 1. The framework.

Step 6. The triangular fuzzy numbers for the most conservative cognition value and the most optimistic cognition value for each CR (EC) were calculated. The triangular fuzzy number for the most conservative cognition value is $C_i = (C_i^l, C_i^m, C_i^u)$, and that for the most optimistic cognition value is $O_i = (O_i^l, O_i^m, O_i^u)$.

Step 7. Experts' opinions wre examined for consensus. Where there was no overlap between the two triangular fuzzy numbers ($C_i^u \le O_i^l$), the experts' opinions were in consensus, and $G_i = (C_i^m + O_i^m)/2$. Where there was an overlap between the two triangular fuzzy numbers ($C_i^u > O_i^l$), a gray zone (Z_i) existed with either situation, $Z_i \le M_i$ or $Z_i > M_i$, where $Z_i = C_i^u - O_i^l$ and $M_i = O_i^m - C_i^m$. If $Z_i \le M_i$, G_i was calculated using the following equations:

$$F_i(x) = \left\{ \int_x \{\min[C_i(x), O_i(x)]\} dx \right\}, i = 1, 2, \ldots, N \tag{1}$$

$$G_i = \{ x \mid \max \mu_{F_i}(x) \}, i = 1, 2, \ldots, N \tag{2}$$

If $Z_i > M_i$, there were discrepancies between the experts' opinions, and experts needed to revise that part of the questionnaire.

Step 8. Critical CRs (ECs) were selected. G_i was compared with the threshold value (τ). If $G_i \ge \tau$, CR (EC) i was selected; if $G_i < \tau$, CR (EC) i was eliminated. The CRs (ECs) with values greater than or equal to the threshold were selected. The threshold was determined according to the subjective opinions of experts, directly affecting the number of CRs (ECs) being selected [37].

Phase 2: Interpretive structural modeling (ISM) [35]

Step 9. The interrelationships among the CRs and among the ECs were determined, along with the influences of CRs on ECs, through applying the ISM. An ISM questionnaire was prepared asking about the interrelationships among the CRs, among the ECs, and among the CRs and ECs. For instance, the relationship between CR_1 and CR_2 could be observed from CR_1 to CR_2, from CR_2 to CR_1, in both directions between CR_1 and CR_2, or CR_1 and CR_2 unrelated.

Step 10. Adjacency matrices for each expert and an integrated adjacency matrix for the CRs (ECs) were built.

Step 10.1. Adjacency matrices for the CRs and for the ECs from each expert were constructed. For example, the adjacency matrix for the CRs from expert k can be represented as follows:

$$\mathbf{D}_{\mathrm{CR}}^k = \begin{array}{c} \\ \mathrm{CR}_1 \\ \mathrm{CR}_2 \\ \vdots \\ \mathrm{CR}_N \end{array} \begin{array}{c} \begin{array}{cccc} \mathrm{CR}_1 & \mathrm{CR}_2 & \cdots & \mathrm{CR}_N \end{array} \\ \begin{bmatrix} 0 & x_{12}^k & \cdots & x_{1N}^k \\ x_{21}^k & 0 & \cdots & x_{2N}^k \\ \vdots & \vdots & 0 & \vdots \\ x_{N1}^k & x_{N2}^k & \cdots & 0 \end{bmatrix} \end{array}, i = 1,2,\ldots,N; j = 1,2,\ldots,N \tag{3}$$

where x_{ij}^k denotes the relationship between CR_i and CR_j assessed by expert k, and x_{ij}^k = 1 if CR_j is reachable from CR_i; otherwise, x_{ij}^k = 0.

Step 10.2. Integrated adjacency matrices were constructed for the CRs and for the ECs. For example, the adjacency matrix for the CRs was formed by integrating the adjacency matrices for the CRs from all experts using the arithmetic mean method. If the calculated value for x_{ij} is greater than or equal to 0.5, let x_{ij} be 1; otherwise, let x_{ij} be 0. The integrated adjacency matrix for the CRs can be represented as follows:

$$\mathbf{D}_{\mathrm{CR}} = \begin{array}{c} \\ \mathrm{CR}_1 \\ \mathrm{CR}_2 \\ \vdots \\ \mathrm{CR}_N \end{array} \begin{array}{c} \begin{array}{cccc} \mathrm{CR}_1 & \mathrm{CR}_2 & \cdots & \mathrm{CR}_N \end{array} \\ \begin{bmatrix} 0 & x_{12} & \cdots & x_{1N} \\ x_{21} & 0 & \cdots & x_{2N} \\ \vdots & \vdots & 0 & \vdots \\ x_{N1} & x_{N2} & \cdots & 0 \end{bmatrix} \end{array}, i = 1, 2, \ldots, N; j = 1, 2, \ldots, N \quad (4)$$

where x_{ij} denotes the relationship between criteria CR_i and CR_j, and x_{ij} = 1 if CR_j is reachable from CR_i; otherwise, x_{ij} = 0.

Step 11. The initial and the final reachability matrices for the CRs (ECs) were calculated.

Step 11.1. The initial reachability matrices for the CRs and the ECs were calculated. Each initial reachability matrix was obtained by adding the integrated adjacency matrix and the unit matrix. For example, the initial reachability matrix for the CRs is expressed as follows:

$$\mathbf{M}_{\mathrm{CR}} = \mathbf{D}_{\mathrm{CR}} + \mathbf{I} \quad (5)$$

Step 11.2. The final reachability matrix was calculated. Convergence was met by using operators of Boolean multiplication and addition. The final reachability matrix reflected the transitivity of the contextual relationships among the CRs (ECs). For instance, the final reachability matrix for the CRs is expressed as follows:

$$\mathbf{M}^*_{\mathrm{CR}} = \mathbf{M}^{\nu}_{\mathrm{CR}} = \mathbf{M}^{\nu+1}_{\mathrm{CR}}, \nu > 1 \quad (6)$$

$$\mathbf{M}^*_{\mathrm{CR}} = \begin{array}{c} \\ \mathrm{CR}_1 \\ \mathrm{CR}_2 \\ \vdots \\ \mathrm{CR}_N \end{array} \begin{array}{c} \begin{array}{cccc} \mathrm{CR}_1 & \mathrm{CR}_2 & \cdots & \mathrm{CR}_N \end{array} \\ \begin{bmatrix} x^*_{11} & x^*_{12} & \cdots & x^*_{1N} \\ x^*_{21} & x^*_{22} & \cdots & x^*_{2N} \\ \vdots & \vdots & x^*_{ij} & \vdots \\ x^*_{N1} & x^*_{N2} & \cdots & x^*_{NN} \end{bmatrix} \end{array}, i = 1, 2, \ldots, N; j = 1, 2, \ldots, N \quad (7)$$

where x^*_{ij} denotes the impact of CR_i on criterion CR_j.

Step 12. A network structure was constructed. Using the final reachability matrices for the CRs and for the ECs, a completed network is developed.

Phase 3: Fuzzy analytic network process–quality function deployment (FANP-QFD) [24,35]

Step 13. A house of quality (HOQ) was developed. Based on the results of step 12, a HOQ consisting of CRs and ECs was constructed, and the interdependence among CRs, the interdependence among ECs, and the impact of CRs on ECs were demonstrated. In a traditional HOQ, a triangular roof is constructed to show the interdependence among ECs, and CRs are assumed to be independent. In this study, not only was a triangular roof employed to represent the interdependence among ECs, but a left-sided triangle was also constructed to represent the interdependence among CRs. Furthermore, while an EC may have an influence on another EC, it may not be affected by that other EC. The same applies to CRs. That is, the effects of CRs and ECs can be directional, which is not considered in the traditional QFD. In this proposed HOQ, a check was entered at the specified position of the triangle if one CR (EC) affected another CR (EC) but not vice versa. If two CRs (ECs) were related to each other, both checks were entered at the specified location. The HOQ can be represented as a network, as shown in Figure 2. Under the goal of developing a mobile payment service framework, the second level contains CRs, and the third level contains ECs. The importance of the CRs is represented by w_{21}. The interdependence among CRs is represented by $\mathbf{W_{22}}$, and the interdependence among ECs is represented by $\mathbf{W_{33}}$. The impact of CRs on ECs is represented by $\mathbf{W}_{32}$.

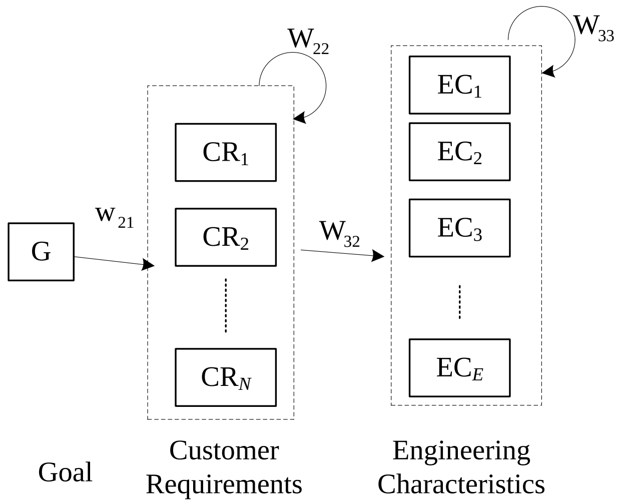

Figure 2. A QFD network structure.

Step 14. Using a questionnaire, experts' opinions were aggregated, and aggregated pairwise comparison matrices were constructed. A pairwise comparison questionnaire based on the HOQ was prepared, and the experts were asked to fill in the questionnaire.

Experts were asked to make pairwise comparisons of elements in the questionnaire using six different linguistic terms, as listed in Table 1. The linguistic variables for pairwise comparisons of each part from each expert questionnaire were converted into triangular fuzzy numbers. For example, a pairwise comparison of CAs with respect to the overall objective from expert k can be expressed as follows:

$$\widetilde{\mathbf{A}}^{k} = \begin{array}{c} \\ \mathrm{CR}_1 \\ \mathrm{CR}_2 \\ \vdots \\ \mathrm{CR}_\mathrm{N} \end{array} \begin{array}{c} \begin{array}{cccc} \mathrm{CR}_1 & \mathrm{CR}_2 & \cdots & \mathrm{CR}_\mathrm{N} \end{array} \\ \begin{bmatrix} 1 & \widetilde{\mathrm{a}}_{12}^{k} & \ldots & \widetilde{\mathrm{a}}_{1\mathrm{N}}^{k} \\ 1/\widetilde{\mathrm{a}}_{12}^{k} & 1 & \ldots & \widetilde{\mathrm{a}}_{2\mathrm{N}}^{k} \\ \vdots & \vdots & 1 & \vdots \\ 1/\widetilde{\mathrm{a}}_{1\mathrm{N}}^{k} & 1/\widetilde{\mathrm{a}}_{2\mathrm{N}}^{k} & \ldots & 1 \end{bmatrix} \end{array} \tag{8}$$

where N is the number of CRs.

Table 1. Membership functions of triangular fuzzy numbers.

Fuzzy Number	Linguistic Variables	Positive Triangular Fuzzy Numbers	Positive Reciprocal Triangular Fuzzy Numbers
$\widetilde{1}$	Equally important	(1, 1, 3)	(1/3, 1, 1)
$\widetilde{3}$	Moderately important	(1, 3, 5)	(1/5, 1/3, 1)
$\widetilde{5}$	Important	(3, 5, 7)	(1/7, 1/5, 1/3)
$\widetilde{7}$	Very important	(5, 7, 9)	(1/9, 1/7, 1/5)
$\widetilde{9}$	Extremely important	(7, 9, 9)	(1/9, 1/9, 1/7)

If there are k experts, a total of k pairwise comparison matrices are available. For each pairwise comparison between two elements, there are k triangular fuzzy numbers. The geometric mean method was used to aggregate the expert responses and a synthetic triangular fuzzy number was obtained:

$$\widetilde{a}_{ij} = \left(\widetilde{a}_{ij}^{1} \otimes \widetilde{a}_{ij}^{2} \otimes \ldots\ldots \otimes \widetilde{a}_{ij}^{k}\right)^{1/k} \tag{9}$$

where $\widetilde{a}_{ij}^{k} = (l_{ij}^{k}, t_{ij}^{k}, u_{ij}^{k})$.

The fuzzy aggregated pairwise comparison matrix was as follows:

$$\widetilde{\mathbf{A}} = \begin{bmatrix} 1 & \widetilde{a}_{12} & \cdots & \cdots & \cdots & \cdots & \widetilde{a}_{1j} \\ 1/\widetilde{a}_{12} & 1 & \cdots & \cdots & \cdots & \cdots & \widetilde{a}_{2j} \\ \vdots & \vdots & 1 & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1 & \widetilde{a}_{ij} & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1/\widetilde{a}_{ij} & 1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & 1 & \cdots \\ 1/\widetilde{a}_{1j} & 1/\widetilde{a}_{2j} & \cdots & \cdots & \cdots & \cdots & 1 \end{bmatrix} \tag{10}$$

where $\widetilde{a}_{ij} = (l_{ij}, t_{ij}, u_{ij})$.

The center of gravity (COG) method was applied next to defuzzify the comparison between elements i and j [38,39]:

$$a_{ij} = \frac{\left[\left(u_{ij} - l_{ij}\right) + \left(t_{ij} - l_{ij}\right)\right]}{3} + l_{ij} \tag{11}$$

The defuzzified aggregated pairwise comparison matrix was as follows:

$$\mathbf{A} = \begin{bmatrix} 1 & a_{12} & \cdots & \cdots & \cdots & \cdots & a_{1j} \\ 1/a_{12} & 1 & \cdots & \cdots & \cdots & \cdots & a_{2j} \\ \vdots & \vdots & 1 & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1 & a_{ij} & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1/a_{ij} & 1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & 1 & \cdots \\ 1/a_{1j} & 1/a_{2j} & \cdots & \cdots & \cdots & \cdots & 1 \end{bmatrix} \tag{12}$$

Step 15. The consistency of the defuzzified aggregated pairwise comparison matrices was ensured, and the priority vectors were obtained for the matrices. A consistency test was performed to check all the experts' pairwise comparison matrices and if necessary, experts were asked to modify the input to the questionnaire.

Through solving the following equation, a local priority vector was derived for each defuzzified aggregate comparison matrix as an estimate of the relative importance associated with the elements being compared [36,40]:

$$\mathbf{A} \cdot w = \lambda_{max} \cdot w \tag{13}$$

where $\mathbf{A}$ is the defuzzified aggregated pairwise comparison matrix, w is the eigenvector, and $\lambda_{\max}$ is the largest eigenvalue of $\mathbf{A}$.

The consistency property of each defuzzified aggregated pairwise comparison matrix were checked via the consistency index (CI) and consistency ratio (CR) [40]:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{14}$$

$$CR = \frac{CI}{\mathrm{RI}} \tag{15}$$

where n is the number of items being compared in the matrix, and RI is a random index, the average consistency index of a randomly generated pairwise comparison matrix of similar size [40]. A CR value exceeding the threshold indicates inconsistent judgments. In this case, the experts needed to modify the original values of a specific part of the questionnaire.

Step 16. An unweighted supermatrix and a weighted supermatrix were developed. The limit supermatrix was computed to derive the priority weights of the ECs.

To obtain global priorities in a system with interdependent influences, the local priority vectors were entered in the corresponding columns of a matrix, known as an unweighted supermatrix:

$$\mathbf{M} = \begin{array}{c} \\ G \\ CR \\ EC \end{array} \begin{array}{c} \begin{array}{ccc} G & CR & EC \end{array} \\ \begin{bmatrix} \mathbf{I} & & \\ w_{\mathbf{21}} & \mathbf{W_{22}} & \\ & \mathbf{W_{32}} & \mathbf{W_{33}} \end{bmatrix} \end{array} \tag{16}$$

where w_{21} is a vector that represents the impact of the goal on CRs, $\mathbf{W_{32}}$ is a matrix that represents the impact of CRs on ECs, $\mathbf{W_{22}}$ indicates the interdependency of CRs, $\mathbf{W}_{33}$ indicates the interdependency of ECs, $\mathbf{I}$ is the identity matrix, and entries of zero correspond to those elements that have no influence. The unweighted supermatrix needed to be transformed first into a weighted supermatrix, which was stochastic, i.e., each column of the matrix summed to unity [36]. The limit supermatrix was calculated by raising the power of the weighted supermatrix so that the supermatrix converged to a stable supermatrix. The priority weights of ECs were obtained from the limit supermatrix.

5. Case Study Applying the Proposed Model

The proposed model was applied to a case study of a mobile payment service firm in Taiwan developing a mobile payment service framework.

Step 1. The problem of developing a mobile payment service framework was defined.

A mobile payment service provider in Taiwan is considering developing a mobile payment service framework. The requirements from both consumers and businesses need to be considered in order to promote the adoption of both parties. Based on these critical requirements, the most important engineering characteristics (ECs) need to be stressed in the service framework development.

Phase 1: FDM

Step 2. A committee of experts in the mobile payment service industry was formed.

After conducting a comprehensive literature review on mobile payment services' current development status, the authors interviewed five industry experts and company managers.

Step 3. List possible CRs and ECs.

Possible CRs and ECs for developing a mobile payment service are listed in Tables 2 and 3, respectively. Due to limited resources, not all these CRs and ECs could be addressed during development. Therefore, the FDM was used to identify the most critical CRs and ECs for the QFD.

Table 2. Candidate consumer requirements (CRs).

CR Candidates	Explanation
Ease of use	How simple and intuitive the mobile payment service framework is for consumers and merchants to operate effectively.
Trustworthiness	The degree to which consumers and merchants rely on the framework's accuracy, security, and consistency of performance and results.
System and service quality	The overall performance, reliability, user satisfaction, and effectiveness of a system or service in meeting user needs.
Technology security	Measures and protocols to protect systems, networks, and data from unauthorized access, attack, damage, or theft.

Table 2. *Cont.*

CR Candidates	Explanation
Social influence	Influence of friends or groups on consumers' attitudes, behavior, and decisions through the use of the mobile payment service.
Innovativeness	The ability of the mobile payment service framework to introduce new, creative features or technologies that significantly improve functionality or user experience.
Self-efficacy	Consumers' and merchants' confidence and ability to effectively use the mobile payment service framework to complete tasks.
Perceived risk	Consumers' and merchants' assessment of the potential negative consequences or uncertainty associated with the use of the mobile payment service framework.
Operational speed	How quickly the mobile payment service framework performs tasks and responds to user input.
Promotions	Marketing campaigns to increase awareness, attract consumers, and encourage participation in the mobile payment service framework through various channels and incentives.
Reliability	The extent to which the mobile payment service framework consistently performs its intended functions without malfunction or failure under normal operating conditions and for a specified period of time.
Cost-effectiveness	The financial advantages or savings gained from using the mobile payment service framework compared with the costs incurred to acquire, implement, and maintain it.
Usefulness	The extent to which the mobile payment service framework effectively meets consumers' and merchants' needs.
Operational efficiency	How efficiently the consumers and merchants use the mobile payment service framework to gain desired results.

Table 3. Candidate engineering characteristics (ECs).

EC Candidates	Explanation
Encryption	Converting information into an encoded format to ensure data confidentiality and security, preventing unauthorized access.
Authentication	Verifying the identity of a user or device to ensure that access is granted to only legitimate and authorized entities.
Fraud detection	Identifying and preventing fraudulent activities by analyzing data patterns, behaviors, and anomalies to protect to prevent financial losses.
Reliability	How consistently and reliably the mobile payment service framework performs its intended function accurately and without failure over time.
Interoperability	Different systems and financial institutions, devices, or applications can work together, exchange information, and use it effectively without compatibility issues. For example, point-of-sale (POS) systems used by merchants.
User interface (UI) design	Creating intuitive, user-friendly, and visually appealing interfaces to enhance user interaction and experience with the mobile payment service framework.
Latency reduction	Reducing the delay between a user's action and the system's response, affecting the perceived speed and performance of the mobile payment service.
Cryptocurrency integration	Involving the integration of digital currencies into systems, enabling the trading, storage, and management of crypto assets across a variety of applications and platforms.
Contactless payments	Using near-field communication (NFC) technology to allow users to conduct secure transactions with the tap of a mobile device.
Cloud computing	The delivery of computing services (such as storage, processing power, and software) over the internet, with flexible, scalable, and reliable infrastructure.
Edge computing	Processing data closer to the source of generation, reducing latency and bandwidth usage and providing faster response times for real-time transaction processing.
Refund for fraud	Reimbursing an injured party for financial losses incurred due to fraudulent activities.

Table 3. *Cont.*

EC Candidates	Explanation
Operation costs	Costs for operating, maintaining, and providing services for the system.
Technical support	Providing reliable assistance and troubleshooting guidance to users encountering issues with the services, aiming to resolve problems promptly and ensure smooth operation.
Offers and bonuses	Providing special offers and accumulating bonuses for the use of services, with incentives provided to consumers, such as discounts, promotions or additional benefits, to encourage usage and loyalty to the services, for example, bonuses and cashback.
Social media and promotions	A platform for consumers to interact with friends and receive special promotions from merchants. Merchants can provide marketing campaigns and special offers for consumers.

Steps 4–8. Select critical CRs (ECs) after calculations.

After carrying out Steps 4 to 8, the results for selecting the critical CRs (ECs) are shown in Tables 4 and 5, respectively. The experts arbitrarily set a threshold value of 7.0 for both CRs and ECs. In total, 8 of out of 14 CRs were selected, and 9 out of 16 ECs were selected, as shown in Table 6.

Table 4. Selection of customer requirements (CRs).

CR Candidates	Minimum Value C_i		Maximum Value O_i		Geometric Mean		Gray Zone Interval Value	Important Degree of Consensus	Selection	CR_i
	Min	Max	Min	Max	C_i	O_i	$M_i - Z_i$	G_i		
Ease of use	7	8	9	10	7.5839	9.5873	3.0034	8.4147	Yes	CR_1
Trustworthiness	2	7	5	9	4.9393	7.8155	0.8762	6.1548	No	-
System and service quality	7	8	9	10	7.1895	9.5873	3.3979	8.5798	Yes	CR_2
Technology security	6	7	8	9	6.5814	8.5858	3.0044	7.4168	Yes	CR_3
Social influence	2	7	5	10	4.7625	7.9819	1.2195	6.1426	No	-
Innovativeness	7	8	9	10	7.7892	9.7915	3.0023	8.2103	Yes	CR_4
Self-efficacy	3	7	6	9	5.0080	7.9170	1.9091	6.4904	No	-
Perceived risk	4	8	6	10	5.4038	7.8726	0.4687	6.8381	No	-
Operation speed	3	8	6	10	6.0688	8.6562	0.5874	7.1580	Yes	CR_5
Promotions	6	7	8	9	6.1879	8.5858	3.3980	7.5809	Yes	CR_6
Reliability	7	8	9	10	7.3841	9.5873	3.2033	8.5119	Yes	CR_7
Cost-effectiveness	7	8	9	10	7.3841	9.3874	3.0034	8.6139	Yes	CR_8
Usefulness	2	8	5	10	3.6411	6.69988	0.0587	5.8417	No	-
Operational efficiency	4	7	6	9	5.8515	8.29897	1.4475	6.6669	No	-

Table 5. Selection of engineering characteristics (ECs).

EC Candidates	Minimum Value C_i		Maximum Value O_i		Geometric Mean		Gray Zone Interval Value	Important Degree of Consensus	Selection	EC_i
	Min	Max	Min	Max	C_i	O_i	$M_i - Z_i$	G_i		
Encryption	5	7	9	10	5.7527	9.1917	5.4390	8.7336	Yes	EC_1
Authentication	6	7	9	10	6.5814	9.1917	4.6102	8.3719	Yes	EC_2
Fraud detection	5	6	7	9	5.7852	8.1649	3.3798	6.1557	No	-
Reliability	3	6	5	9	4.2823	7.2067	1.9245	5.5623	No	-
Interoperability	5	8	7	10	5.4928	7.9300	1.4372	7.2706	Yes	EC_3
User interface (UI) design	5	8	7	10	6.6939	8.7194	1.0255	7.5683	Yes	EC_4
Latency reduction	4	8	6	10	5.8274	8.2784	0.4510	7.0238	Yes	EC_5
Cryptocurrency integration	3	6	7	9	4.6821	7.9748	4.2928	6.5748	No	-

Table 5. *Cont.*

EC Candidates	Minimum Value C_i		Maximum Value O_i		Geometric Mean		Gray Zone Interval Value	Important Degree of Consensus	Selection	EC_i
	Min	Max	Min	Max	C_i	O_i	$M_i - Z_i$	G_i		
Contactless payments	5	7	8	9	5.9663	8.7905	3.8242	7.5667	Yes	EC_6
Cloud computing	4	7	8	9	5.8845	8.7905	3.9059	7.5853	Yes	EC_7
Edge computing	6	8	9	10	7.3537	9.7915	3.4378	8.4495	Yes	EC_8
Refund for fraud	5	6	7	9	5.5780	8.1393	3.5613	6.2703	No	-
Operational costs	4	7	8	9	5.5016	8.58581	4.0843	7.7189	Yes	EC_9
Technical support	4	7	6	9	4.8914	7.27741	1.3860	6.3773	No	-
Offers and bonuses	4	6	7	9	5.1435	8.16493	4.0214	6.4237	No	-
Social media and promotions	3	5	6	8	3.7279	6.73173	4.0038	5.6348	No	-

Table 6. Selected CRs and ECs.

Selected CRs	CR Name	Selected ECs	EC Name
CR_1	Ease of use	EC_1	Encryption
CR_2	System and service quality	EC_2	Authentication
CR_3	Technology security	EC_3	Interoperability
CR_4	Innovativeness	EC_4	User interface (UI) design
CR_5	Operational speed	EC_5	Latency reduction
CR_6	Promotions	EC_6	Contactless payments
CR_7	Reliability	EC_7	Cloud computing
CR_8	Cost-effectiveness	EC_8	Edge computing
		EC_9	Operational costs

Phase 2: ISM

Step 9. Determine the interrelationships among the CRs and among the ECs and the influences of CRs on ECs.

After the critical CRs and ECs were selected, an ISM questionnaire was given out to the experts to determine the interrelationships among the CRs and among the ECs and influence of CRs on ECs.

Step 10. Build adjacency matrices for each expert and an integrated adjacency matrix for the CRs (ECs).

Adjacency matrices for each expert's evaluation of the interrelationships among the CRs and among the ECs and influences of CRs on ECs were built first. For example, the adjacency matrix for Expert 1's evaluation of the interrelationships among CRs is as shown in Table 7. Integrated adjacency matrices for the CRs, for the ECs, and among the CRs and ECs were formed. For example, using the arithmetic mean method, the adjacency matrix for the CRs was formed by integrating the adjacency matrices for the CRs from all experts. If the arithmetic mean of one CR in relation to the other CR was greater than or equal to 0.5, the relation was set to 1; otherwise, it was set to 0. The integrated adjacency matrix for the CRs is shown in Table 8.

Table 7. Adjacency matrix $\mathbf{D}^1_{\mathrm{CR}}$ among CRs, according to Expert 1.

	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_1	0	1	1	0	1	0	1	0
CR_2	1	0	1	0	0	0	0	1
CR_3	0	1	0	1	1	0	1	1

Table 7. *Cont.*

	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_4	1	1	1	0	1	0	1	0
CR_5	1	1	0	1	0	0	1	1
CR_6	0	1	0	1	1	0	1	1
CR_7	1	1	1	1	0	0	0	1
CR_8	0	1	1	1	1	0	1	0

Table 8. Adjacency matrix $\mathbf{D}_{CR}$ among CRs.

	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_1	0	1	1	1	0	0	0	0
CR_2	1	0	1	1	1	0	1	0
CR_3	0	0	0	1	0	0	1	0
CR_4	0	0	0	0	0	0	0	0
CR_5	1	1	1	1	0	0	1	0
CR_6	0	0	0	1	0	0	0	0
CR_7	1	1	1	1	1	0	0	0
CR_8	1	0	1	1	0	0	1	0

Step 11. Calculate the initial and the final reachability matrices for the CRs (ECs).

The initial reachability matrix $\mathbf{M}_{CR}$ for CRs was as follows:

$$\mathbf{M}_{CR} = \mathbf{D}_{CR} + \mathbf{I} = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

The final reachability matrix $\mathbf{M}^*_{CR}$ was as follows:

$$\mathbf{M}^*_{CR} = \mathbf{M}^2_{CR} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 \end{bmatrix}$$

Step 12. Construct a network structure.

Based on $\mathbf{M}^*_{CR}$, the interrelationships among the CRs are depicted in Figure 3. For example, the first row of $\mathbf{M}^*_{CR}$ shows the influence of other CRs on CR_1. Since all CRs (with a value of 1) have influences on CR_1 except CR_6 and CR_8 (with a value of 0), the arrows from all CRs, except CR_6 and CR_8, to CR_1 can be observed in Figure 3. The same process was performed again to determine the influences of CRs on ECs and the interrelationships among ECs, as shown in Figures 4 and 5, respectively.

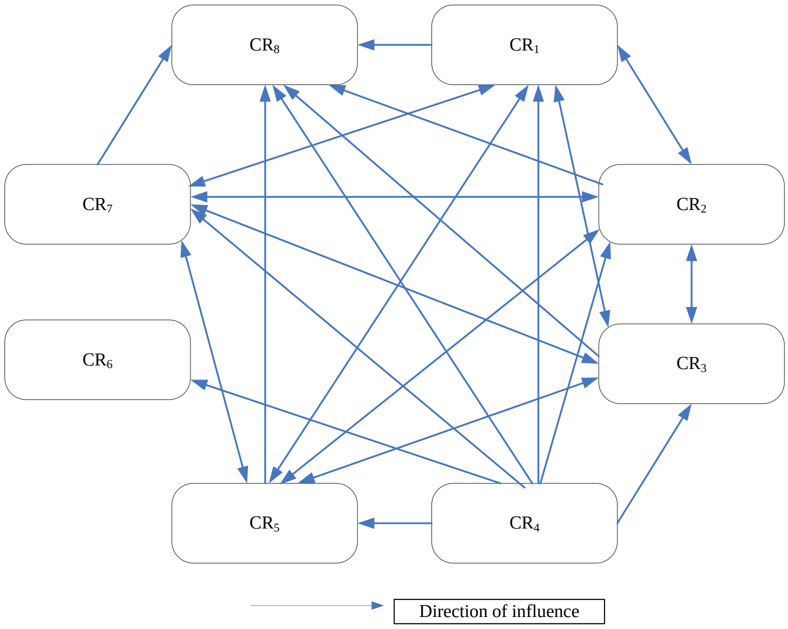

Figure 3. Interrelationships among CRs.

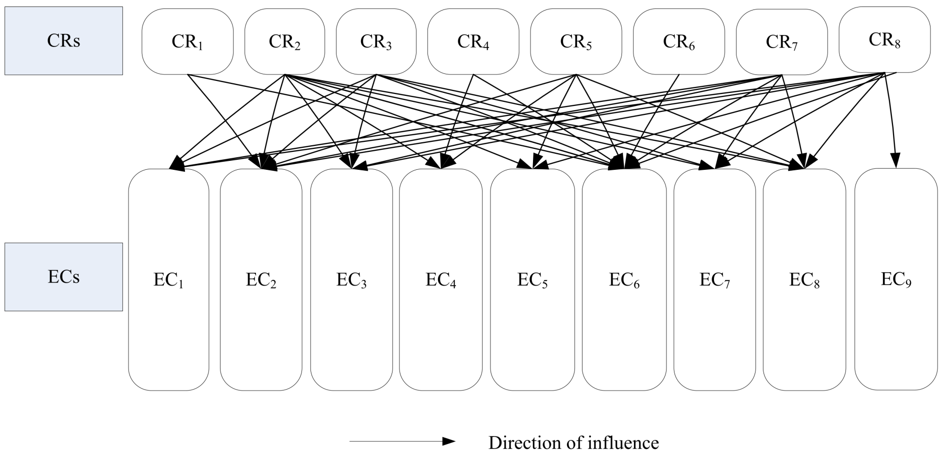

Figure 4. The influences of CRs on ECs.

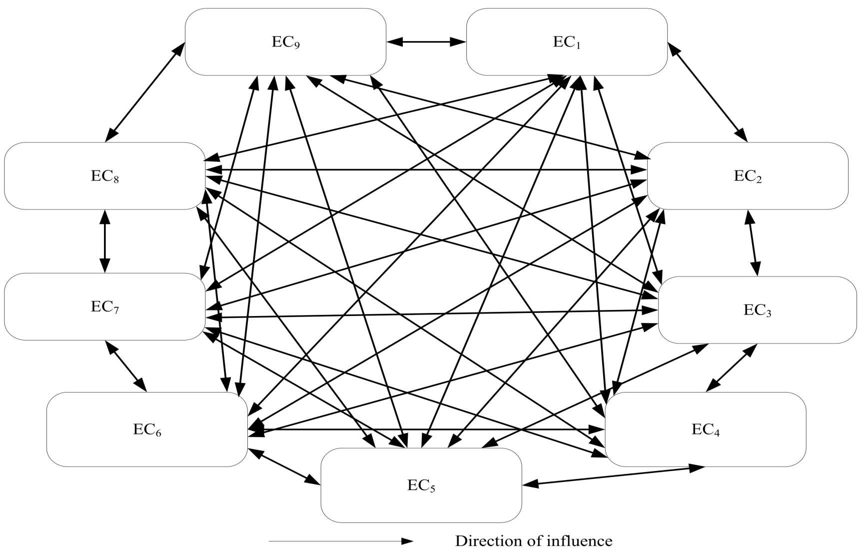

Figure 5. The interrelationships among ECs.

Phase 3: FANP-QFD

Step 13. Develop a house of quality (HOQ).

Based on the results from Phase 3, i.e., Figures 3–5, an HOQ was built, as shown in Figure 6, which was then used to construct a QFD network.

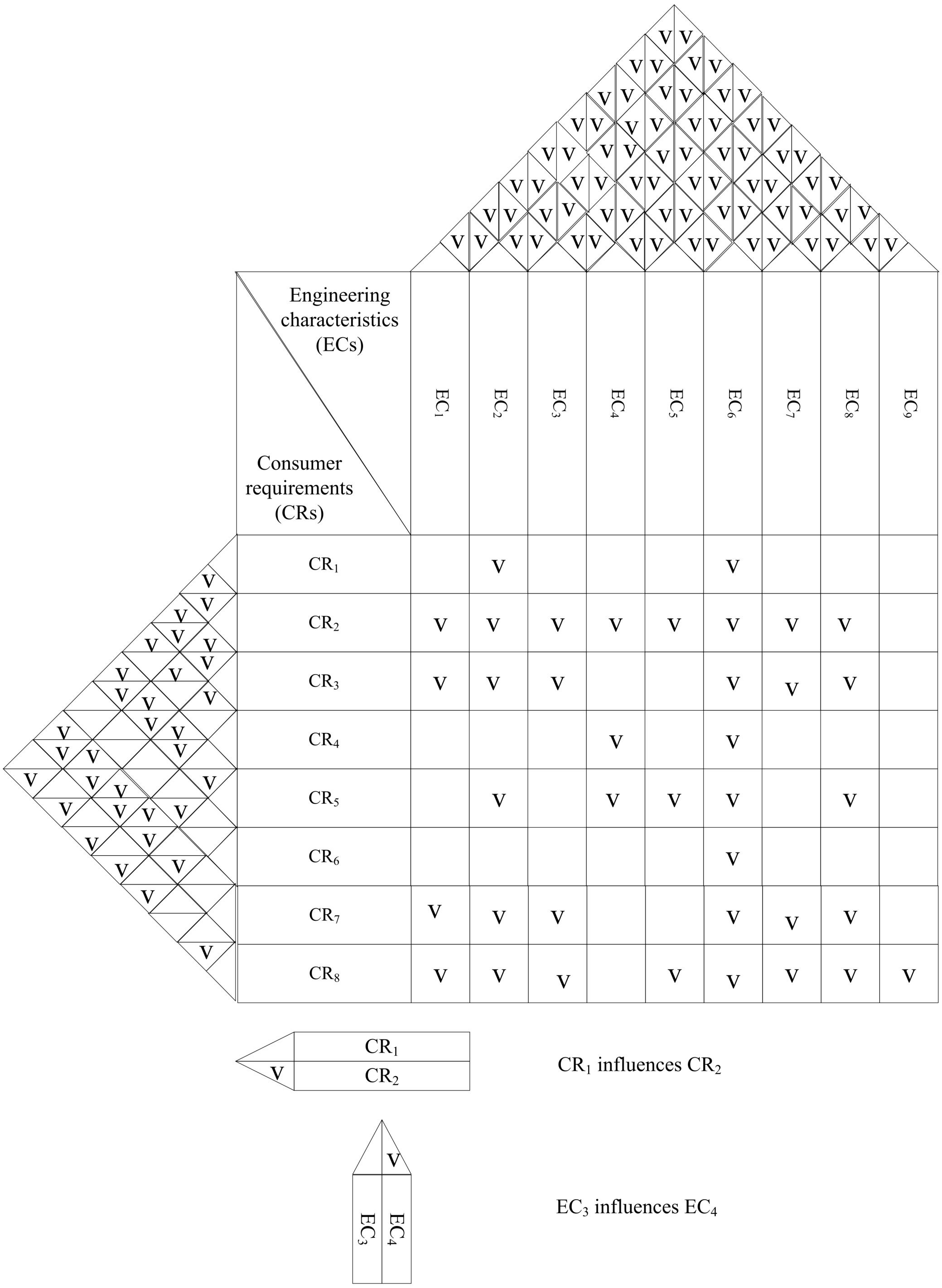

Figure 6. House of quality (HOQ).

Step 14. Use a questionnaire, aggregate experts' opinions, and construct aggregated pairwise comparison matrices.

Experts were asked via a questionnaire to compare the elements pairwise using the nine different linguistic terms shown in Table 1. For example, based on the questionnaire result from Expert 1, a fuzzy pairwise comparison matrix for the importance of CRs was formed, as shown in Table 9. The geometric mean method was used to aggregate the expert responses, and a fuzzy aggregated pairwise comparison matrix for the importance of CRs was constructed, as shown in Table 10. Then, the defuzzified aggregated pairwise comparison matrix for the importance of CRs was constructed, as shown in Table 11.

Table 9. Fuzzy pairwise comparison matrix for the importance of CRs, according to Expert 1.

Goal	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_1	(1, 1, 1)	(1/5, 1/3, 1)	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)
CR_2	(1, 3, 5)	(1, 1, 1)	(3, 5, 7)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)	(1, 3, 5)	(5, 7, 9)
CR_3	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 3, 5)	(1/5, 1/3, 1)	(1, 3, 5)	(1/5, 1/3, 1)	(3, 5, 7)
CR_4	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1, 1, 1)	(1/7, 1/6, 1/5)	(1, 3, 5)	(1/5, 1/3, 1)	(1, 3, 5)
CR_5	(1/5, 1/3, 1)	(1/5, 1/3, 1)	(1, 3, 5)	(3, 5, 7)	(1, 1, 1)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)
CR_6	(1/5, 1/3, 1)	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1/5, 1/3, 1)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1/7, 1/6, 1/5)	(1, 3, 5)
CR_7	(1/5, 1/3, 1)	(1/5, 1/3, 1)	(1, 3, 5)	(1, 3, 5)	(1/5, 1/3, 1)	(3, 5, 7)	(1, 1, 1)	(3, 5, 7)
CR_8	(1/5, 1/3, 1)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1/7, 1/5, 1/3)	(1/5, 1/3, 1)	(1/7, 1/5, 1/3)	(1, 1, 1)

Table 10. Fuzzy aggregated pairwise comparison matrix for the importance of CRs.

Goal	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_1	(1, 1, 1)	(0.65, 0.89, 1.48)	(3.27, 5.52, 7.61)	(3.32, 5.35, 7.36)	(1.55, 2.95, 4.15)	(2.14, 4.36, 6.43)	(1.55, 3.68, 5.72)	(1.72, 3.94, 6.02)
CR_2	(0.68, 1.12, 1.53)	(1, 1, 1)	(2.95, 5.16, 7.24)	(3.27, 5.52, 7.61)	(1.55, 2.37, 3.00)	(3.32, 5.35, 7.36)	(1.55, 2.95, 4.15)	(3.68, 5.72, 7.74)
CR_3	(0.14, 0.18, 0.31)	(0.14, 0.19, 0.34)	(1, 1, 1)	(1.55, 2.37, 3.00)	(0.24, 0.34, 0.64)	(1.25, 2.67, 3.88)	(0.33, 0.42, 0.64)	(2.95, 5.16, 7.24)
CR_4	(0.14, 0.19, 0.30)	(0.13, 0.18, 0.31)	(0.33, 0.42, 0.64)	(1, 1, 1)	(0.14, 0.19, 0.33)	(1.55, 2.37, 3.00)	(0.24, 0.34, 0.64)	(1.55, 2.95, 4.15)
CR_5	(0.24, 0.34, 0.64)	(0.33, 0.42, 0.64)	(1.55, 2.95, 4.15)	(2.96, 5.16, 7.24)	(1, 1, 1)	(3.50, 5.81, 7.61)	(1.55, 2.37, 3.00)	(3.68, 5.72, 7.74)
CR_6	(0.16, 0.23, 0.47)	(0.14, 0.19, 0.30)	(0.26, 0.37, 0.80)	(0.33, 0.42, 0.64)	(0.13, 0.17, 0.29)	(1, 1, 1)	(0.13, 0.18, 0.31)	(1.55, 2.37, 3.00)
CR_7	(0.17, 0.27, 0.64)	(0.24, 0.34, 0.64)	(1.55, 2.37, 3.00)	(1.55, 2.95, 4.15)	(0.33, 0.42, 0.64)	(3.27, 5.52, 7.61)	(1, 1, 1)	(1.72, 3.94, 6.02)
CR_8	(0.17, 0.25, 0.58)	(0.13, 0.17, 0.27)	(0.14, 0.19, 0.34)	(0.24, 0.34, 0.64)	(0.13, 0.17, 0.27)	(0.33, 0.42, 0.64)	(0.17, 0.25, 0.58)	(1, 1, 1)

Table 11. Defuzzified aggregated pairwise comparison matrix for the importance of CRs.

Goal	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8
CR_1	1	1.006	5.469	5.344	2.884	4.312	3.651	3.890
CR_2	0.994	1	5.118	5.469	2.309	5.344	2.884	5.714
CR_3	0.183	0.195	1	2.309	0.408	2.596	0.466	5.118
CR_4	0.187	0.183	0.433	1	0.221	2.309	0.408	2.884
CR_5	0.347	0.433	2.451	4.523	1	5.639	2.309	5.714
CR_6	0.232	0.187	0.385	0.433	0.177	1	0.206	2.309
CR_7	0.274	0.347	2.145	2.451	0.433	4.854	1	3.890
CR_8	0.257	0.175	0.195	0.347	0.175	0.433	0.257	1
$\lambda_{max} = 8.595$ CI = 0.085 RI = 1.41 CR = 0.061								

Step 15. Ensure the consistency of defuzzified aggregated pairwise comparison matrices and obtain the priority vectors for the matrices.

A consistency test was performed to check each defuzzified aggregated pairwise comparison matrix. If the test were not passed, experts would need to revise the original values in the specific part of the questionnaire. The priority vector for each matrix was calculated. For example, the consistency index (*CI*) and consistency ratio (*CR*) for the defuzzified aggregated pairwise comparison matrix for the importance of the CRs were 0.085 and 0.061, as shown in Table 10. Since CR was less than 0.1, the test was passed. The priority vector for the CRs is:

$$\mathbf{A} * w = \lambda_{\max} * w, w = \begin{bmatrix} 0.27441 \\ 0.26174 \\ 0.07619 \\ 0.05021 \\ 0.16387 \\ 0.03710 \\ 0.10742 \\ 0.02907 \end{bmatrix}$$

The result showed that CR_1 (ease of use) was held to be the most important CR, with a priority of 0.27441, followed by CR_2 (system and service quality) with a priority of 0.26174, CR_5 (operation speedal) with a priority of 0.16387, and CR_7 (reliability) with a priority of 0.10742. With relatively higher priorities compared with the others, CR_1 and CR_2 are extremely important.

Step 16. Develop an unweighted supermatrix and a weighted supermatrix. Compute the limit supermatrix to derive the priority weights of the ECs.

The unweighted supermatrix is shown in Table 12. A weighted supermatrix was constructed such that the sum of each column was equal to 1. The limit supermatrix was calculated by raising the weighted supermatrix to a power to obtain a converged state, as shown in Table 13. The (3,1) block of the limit supermatrix shows the priority weights of the ECs.

Table 12. Unweighted supermatrix.

	G	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**CR_6**	**CR_7**	**CR_8**	**EC_1**	**EC_2**	**EC_3**	**EC_4**	**EC_5**	**EC_6**	**EC_7**	**EC_8**	**EC_9**
G	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_1	0.27441	0.26605	0.36578	0.30836	0	0	0	0.1661	0.19537	0	0	0	0	0	0	0	0	0
CR_2	0.26174	0.20038	0.34954	0.31466	0	0.13501	0	0.17743	0.14606	0	0	0	0	0	0	0	0	0
CR_3	0.07619	0.17656	0	0.31098	0	0	0	0.09274	0.13401	0	0	0	0	0	0	0	0	0
CR_4	0.05021	0.16401	0	0.00019	1	0	0.72452	0.15274	0.13865	0	0	0	0	0	0	0	0	0
CR_5	0.16387	0.10912	0.08387	0.00019	0	0.42308	0	0.17151	0.134	0	0	0	0	0	0	0	0	0
CR_6	0.03710	0	0	0	0	0	0.27548	0	0	0	0	0	0	0	0	0	0	0
CR_7	0.10742	0.08389	0.20082	0.06563	0	0.44191	0	0.23949	0.137	0	0	0	0	0	0	0	0	0
CR_8	0.02907	0	0	0	0	0	0	0	0.11492	0	0	0	0	0	0	0	0	0
EC_1	0	0	0.13128	0.19831	0	0	0	0.26613	0.16735	0.16445	0.11249	0.14624	0.22233	0.1329	0.05102	0.16223	0.13571	0.25118
EC_2	0	0.20547	0.11479	0.18169	0	0.30968	0	0.20596	0.16759	0.08503	0.09295	0.10831	0.1076	0.13085	0.21036	0.14832	0.09656	0.16565
EC_3	0	0	0.1754	0.19199	0	0	0	0.16867	0.16666	0.15119	0.0857	0.14513	0.10578	0.10835	0.12728	0.10596	0.15181	0.05299
EC_4	0	0	0.14334	0	0.70309	0.24495	0	0	0	0.09151	0.09348	0.14555	0.12277	0.12044	0.05383	0.11726	0.17537	0.05362
EC_5	0	0	0.12806	0	0	0.18648	0	0	0.12685	0.09305	0.08554	0.11646	0.07992	0.11739	0.11792	0.09095	0.09499	0.05322
EC_6	0	0.79453	0.11483	0.15403	0.29691	0.13883	1	0.13369	0.08614	0.06804	0.07607	0.09968	0.09448	0.10786	0.20023	0.09586	0.05702	0.05292
EC_7	0	0	0.0865	0.12082	0	0	0	0.11856	0.11336	0.09143	0.05803	0.09935	0.08602	0.0877	0.14967	0.1479	0.05573	0.05411
EC_8	0	0	0.1058	0.15316	0	0.12006	0	0.10698	0.09611	0.09956	0.3658	0.09807	0.09496	0.09977	0.04799	0.06548	0.15743	0.05257
EC_9	0	0	0	0	0	0	0	0	0.07593	0.15574	0.02994	0.04122	0.08614	0.09474	0.0417	0.06603	0.07539	0.26373

Table 13. Limit supermatrix.

	G	**CR_1**	**CR_2**	**CR_3**	**CR_4**	**CR_5**	**CR_6**	**CR_7**	**CR_8**	**EC_1**	**EC_2**	**EC_3**	**EC_4**	**EC_5**	**EC_6**	**EC_7**	**EC_8**	**EC_9**
G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CR_8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EC_1	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346	0.15346
EC_2	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177	0.12177
EC_3	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796	0.11796
EC_4	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016	0.11016

Table 13. *Cont.*

	G	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8	EC_1	EC_2	EC_3	EC_4	EC_5	EC_6	EC_7	EC_8	EC_9
EC_5	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428	0.09428
EC_6	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113	0.09113
EC_7	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965	0.08965
EC_8	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641	0.12641
EC_9	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518	0.09518

The result showed that EC_1 (encryption) was regarded as the most important EC, with a priority of 0.15346, followed by EC_8 (edge computing) with a priority of 0.12641, EC_2 (authentication) with a priority of 0.12177, EC_3 (interoperability) with a priority of 0.11796, and EC_4 (user interface (UI) design) with a priority of 0.11016. With a relatively higher priority compared to others, EC_1 is extremely important.

6. Conclusions

In today's dynamic business environment, through aligning product or service attributes with customer needs and market expectations, firms can boost competitiveness, drive innovation, and achieve sustained success. This research constructs a model for developing a mobile payment service framework that both consumers and businesses are willing to adopt. In this model, fuzzy set theory, the Delphi method, interpretive structural modeling (ISM), QFD, and ANP are applied. Fuzzy set theory is integrated with the other methods to address the fuzziness and uncertainty in experts' information when filling out questionnaires. The Delphi method is a structured process using a series of questionnaires to gather information and achieve group consensus among experts. Through applying the fuzzy Delphi method (FDM), critical customer requirements (CRs) and engineering characteristics (ECs) can be selected for further analysis. This ensures that only the most important CRs and ECs are incorporated into the rest of the model, preventing unnecessary and cumbersome analysis. Interpretive structural modeling (ISM) is used to determine whether there are significant interrelationships between factors, and whether these relationships are two-directional. The ISM can thus be applied to understand relationships among CRs and among ECs, as well as the effects of CRs on ECs. This helps reduce the number of pairwise comparisons required in the fuzzy analytic network process (FANP) via eliminating insignificant relationships. Instead of prioritizing CRs and ECs using a linear point-scoring scale under conventional QFD, the FANP is incorporated. This allows experts to systematically conduct pairwise comparison of factors, ensuring consistency in their opinions. The FANP also simultaneously evaluates the interrelationships among factors, providing more holistic and accurate prioritization.

The case study results show that the most important consumer requirements for a mobile payment service framework are ease of use, system and service quality, and operational speed, in descending order. Ease of use has the highest priority, in agreement with many past works that adopt theories such as the technology acceptance model (TAM). Both consumers and merchants want a simple and intuitive mobile payment service framework so that they can operate the system efficiently. They are also concerned with the system's performance, reliability, satisfaction, and effectiveness. In addition, they desire a system that can complete the task quickly. The result shows that in terms of engineering characteristics, encryption, edge computing, authentication, and interoperability are the most important, in descending order. Encryption is an essential component of the security infrastructure of mobile payment services, protecting users and service providers from various cyber threats. Edge computing enhances mobile payments via reducing latency, improving security, ensuring reliability, optimizing bandwidth, and providing instant, localized processing. Authentication ensures security, prevents fraud, protects user data, and maintains trust through verifying the identity of users in mobile payment services. With potential security risks, including data breaches, unauthorized access, and fraud, strong countermeasures need encryption and authentication, as well as regular security audits and monitoring of instant transactions. Interoperability ensures seamless transactions across different platforms, financial institutions, and payment networks, as well as broad user adoption, system compatibility, and an enhanced user experience. In addition, a mobile payment system must have a flexible scale to ensure reliability, fast processing, and strong security to cope with growing transaction volumes. Artificial intelligence and machine learning have future applications in personalizing and securing mobile payments. They will enable personalized mobile payments through analysis of user behavior to customize experiences and optimize transactions. They will enhance security with instant fraud detection, biometric authentication, and predictive analytics to ensure a safe and efficient payment process. These aspects can also be considered when developing mobile payment service frameworks.

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References

1. Karnouskos, S. Mobile payment: A journey through exiting procedures and standardization initiatives. *IEEE Commun. Surv. Tutor.* **2004**, *6*, 44–66. [CrossRef]
2. P.H., H. Mobile payment service adoption: Understanding customers for an application of emerging financial technology. *Inf. Comput. Secur.* **2023**, *31*, 145–171. [CrossRef]
3. Liu, J.; Kauffman, R.J.; Ma, D. Competition, cooperation, and regulation: Understanding the evolution of the mobile payments technology ecosystem. *Electron. Commer. Res. Appl.* **2015**, *14*, 372–391. [CrossRef]
4. Taylor, E. Mobile payment technologies in retail: A review of potential benefits and risks. *Int. J. Retail Distrib. Manag.* **2016**, *44*, 159–177. [CrossRef]
5. Jegerson, D.; Hussain, M. A framework for measuring the adoption factors in digital mobile payments in the COVID-19 era. *Int. J. Pervasive Comput. Commun.* **2023**, *19*, 596–623. [CrossRef]
6. Au, Y.A.; Kauffman, R.J. The economics of mobile payments: Understanding stakeholder issues for an emerging financial technology application. *Electron. Commer. Res. Appl.* **2008**, *7*, 141–164. [CrossRef]
7. Raina, V.K. Overview of Mobile Payment: Technologies and Security. In *Banking, Finance, and Accounting: Concepts, Methodologies, Tools, and Applications*; Information Resources Management Association, Ed.; IGI Global: Hershey, PA, USA, 2015; pp. 180–217.
8. Wang, R.; Peters, M. Consumer intention to switch from cash to mobile payment in restaurants during and after pandemic. *J. Qual. Assur. Hosp. Tour.* **2023**, *in press*. [CrossRef]
9. Fang, C.C.; Liou, J.J.H.; Huang, S.-W.; Wang, Y.-C.; Huang, H.-H.; Tzeng, G.-H. A hybrid, data-driven causality exploration method for exploring the key factors affecting mobile payment usage intention. *Mathematics* **2021**, *9*, 1185. [CrossRef]
10. Oliveira, T.; Thomas, M.; Baptista, G.; Campos, F. Mobile payment: Understanding the determinants of customer adoption and intention to recommend the technology. *Comput. Hum. Behav.* **2016**, *61*, 404–414. [CrossRef]
11. Fu, H.-P.; Chang, T.-S.; Wang, C.-N.; Hsu, H.-P.; Liu, C.-H.; Yeh, C.-Y. Critical factors affecting the introduction of mobile payment tools by microretailers. *Technol. Forecast. Soc. Chang.* **2022**, *175*, 121319. [CrossRef]
12. De Luna, I.R.; Liébana-Cabanillas, F.; Sánchez-Fernández, J.; Muñoz-Leiva, F. Mobile payment is not all the same: The adoption of mobile payment systems depending on the technology applied. *Technol. Forecast. Soc. Chang.* **2019**, *146*, 931–944. [CrossRef]
13. Hsieh, P.-J. Understanding medical consumers' intentions to switch from cash payment to medical mobile payment: A perspective of technology migration. *Technol. Forecast. Soc. Chang.* **2021**, *173*, 121074. [CrossRef]
14. Flavián, C.; Guinaliu, M.; Lu, Y. Mobile payments adoption—Introducing mindfulness to better understand consumer behavior. *Int. J. Bank Mark.* **2020**, *38*, 1575–1599. [CrossRef]
15. Liébana-Cabanillas, F.; Japutra, A.; Molinillo, S.; Singh, N.; Sinha, N. Assessment of mobile technology use in the emerging market: Analyzing intention to use m-payment services in India. *Telecommun. Policy* **2020**, *44*, 102009. [CrossRef]
16. Liao, S.-H.; Widowati, R.; Tang, W. Social media, mobile payment, and mobile gaming for intentional and behavioral recommendations. *Int. J. Hum.-Comput. Interact.* **2024**, *in press*. [CrossRef]
17. Zhang, Q.; Khan, S.; Cao, M.; Khan, S.U. Factors determining consumer acceptance of NFC mobile payment: An extended mobile technology acceptance model. *Sustainability* **2023**, *15*, 3664. [CrossRef]
18. Yeh, H.P. Factors in the ecosystem of mobile payment affecting its use: From the customers' perspective in Taiwan. *J. Theor. Appl. Electron. Commer. Res.* **2020**, *15*, 13–29. [CrossRef]
19. Hsiao, T.Y. Establish standards of standard costing with the application of convergent gray zone test. *Eur. J. Oper. Res.* **2006**, *168*, 593–611. [CrossRef]
20. Lee, A.H.I.; Wang, W.M.; Lin, T.Y. An evaluation framework for technology transfer of new equipment in high technology industry. *Technol. Forecast. Soc. Chang.* **2010**, *77*, 135–150. [CrossRef]

21. Tang, J.; Fung, R.Y.K.; Xu, B. A new approach to quality function deployment planning with financial consideration. *Comput. Oper. Res.* **2002**, *29*, 1447–1463. [CrossRef]
22. Wang, W.M.; Lee, A.H.I.; Chang, D.T. An integrated FDM-ANP evaluation model for sustainable development of housing community. *Optim. Lett.* **2010**, *4*, 239–257. [CrossRef]
23. Wang, Y.; Yeo, G.-T.; Ng, A.Y. Choosing optimal bunkering ports for liner shipping companies: A hybrid fuzzy-Delphi–TOPSIS approach. *Transp. Policy* **2014**, *35*, 358–365. [CrossRef]
24. Lee, A.H.I.; Kang, H.Y.; Lin, C.Y.; Chen, J.S. A novel fuzzy quality function deployment framework. *Qual. Technol. Quant. Manag.* **2017**, *14*, 44–73. [CrossRef]
25. Warfield, J.N. Developing interconnected matrices in structural modeling. *IEEE Trans. Syst. Man Cybern.* **1974**, *4*, 51–81.
26. Warfield, J.N. Toward interpretation of complex structural modeling. *IEEE Trans. Syst. Man Cybern.* **1974**, *4*, 405–417. [CrossRef]
27. Warfield, J.N. *Societal Systems: Planning, Policy and Complexity*; John Wiley & Sons: New York, NY, USA, 1976.
28. Huang, J.J.; Tzeng, G.H.; Ong, C.S. Multidimensional data in multidimensional scaling using the analytic network process. *Pattern Recognit. Lett.* **2005**, *26*, 755–767. [CrossRef]
29. Lee, A.H.I.; Lin, C.Y.; Wang, S.R.; Tu, Y.M. The construction of a comprehensive model for production strategy evaluation. *Fuzzy Optim. Decis. Mak.* **2010**, *9*, 187–217. [CrossRef]
30. Zheng, X.; Pulli, P. Extending quality function deployment to mobile services design and development. *Control Eng. Appl. Inform.* **2005**, *7*, 42–49.
31. Wicaksono, T.; Illés, C.B.; Dunay, A. Enhancing collaborative apparel consumption model: Quality-driven insights from customers and industry professionals. *J. Open Innov. Technol. Mark. Complex.* **2023**, *9*, 100077. [CrossRef]
32. Singh, A.; Kumar, S. Picture fuzzy set and quality function deployment approach based novel framework for multi-criteria group decision making method. *Eng. Appl. Artif. Intell.* **2021**, *104*, 104395. [CrossRef]
33. Karsak, E.E.; Sozer, S.; Alptekin, S.E. Product planning in quality function deployment using a combined analytic network process and goal programming approach. *Comput. Ind. Eng.* **2002**, *44*, 171–190. [CrossRef]
34. Lee, A.H.I.; Kang, H.Y.; Yang, C.Y.; Lin, C.Y. An evaluation framework for product planning using FANP, QFD and multi-choice goal programming. *Int. J. Prod. Res.* **2010**, *48*, 3977–3997. [CrossRef]
35. Lin, C.-Y.; Lee, A.H.I.; Kang, H.-Y. An integrated new product development framework—An application on green and low-carbon products. *Int. J. Syst. Sci.* **2015**, *46*, 733–753. [CrossRef]
36. Saaty, T.L. *Decision Making with Dependence and Feedback: The Analytic Network Process*; RWS Publications: Pittsburgh, PA, USA, 1996.
37. Dzeng, R.J.; Wen, K.S. Evaluating project teaming strategies for construction of Taipei101 using resource-based theory. *Int. J. Proj. Manag.* **2005**, *23*, 483–491. [CrossRef]
38. Yager, R.R. Fuzzy decision making including unequal objectives. *Fuzzy Sets Syst.* **1978**, *1*, 87–95. [CrossRef]
39. Klir, G.I.; Yuan, B. *Fuzzy Sets and Fuzzy Logic: Theory and Applications*; Prentice-Hall International: London, UK, 1995.
40. Saaty, T.L. *The Analytic Hierarchy Process*; McGraw-Hill: New York, NY, USA, 1980.