Exploring the Impact of Perceived Risk on User's Mobile Payment Adoption

Chun-Lung Chen*
Ph.D. Program in Business, Feng Chia University, Taiwan

Wen-Hsiang Lai
Department of Marketing, Feng Chia University, Taiwan

ABSTRACT

The actual adoption rate of mobile payment in Taiwan is lower than expected. In order to understand the impact of perceived risk on users' mobile payment adoption, this study identified five main factors and eighteen sub-factors through a literature review and an expert questionnaire and then used an AHP questionnaire to find out the decision weights of these factors. The weights of the five main factors from high to low are perceived usefulness, perceived ease of use, facilitating conditions, perceived risk, and social influence. The top six sub-factors are system stability, convenience, transaction speed, user interface, transaction flexibility, and system performance, which belong to perceived usefulness and perceived ease of use, respectively. In addition, this study adopts Fuzzy AHP to analyze the moderate impact of perceived risk on other main factors. The results show that when the importance of perceived usefulness reaches medium to high and perceived ease of use reaches a high level, the negative impact of perceived risk can be more effectively reduced. Therefore, this study suggests that service providers should strengthen the most important sub-factors of perceived usefulness and perceived ease of use to reduce the negative impact and increase the adoption rate of mobile payment services.

Keywords: Mobile payment adoption; Perceived risk; Analytic Hierarchy Process.

Received 12 December 2021 | Revised 6 March 2022 | Accepted 17 May 2022.

1. INTRODUCTION

The rapid development of information technology in the past ten years has driven the growth of the global digital economy and human beings have gradually entered a digital society. Ford and Khan (2019) addressed that payment in a digital society will be mainly carried out through mobile devices. In addition, the potential use of mobile payment is

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

huge and it is receiving global attention as an alternative to cash payment (Liébana-Cabanillas, Japutra, Molinillo, Singh, and Sinha, 2020). Mobile payment is a digital payment method that uses mobile devices such as smartphones and personal digital assistants (PDA) with wireless capabilities. This transaction method can replace cash, physical credit cards, or checks to pay for various goods or services. Using mobile payment services has many direct benefits for consumers and businesses. Consumers can use mobile payment services to enjoy fast mobile payment services and convenient payment methods. For merchants, mobile payment services are expected to increase transaction volume, reduce transaction costs and increase customer loyalty (Slade, Williams, and Dwivedi, 2013). Despite these benefits, mobile payment services still face challenges in consumer adoption and use (Kaur, Dhir, Singh, Sahu, and Almotairi, 2020).

In order to accelerate the popularization of electronic payments, the Taiwan government has listed the promotion of mobile payment as one of its important policies and has set the goal of reaching 90% of mobile payment penetration by 2025. However, according to the National Development Council's (NDC Taiwan, 2020) report, the penetration rate of mobile payment based on population statistics only reached 37.7%. This report also pointed out that the penetration rate of mobile payment in Taiwan may be affected by system problems and users' concerns about information security. Lin, Lin and Ding (2020) addressed that the actual adoption rate of Taiwan's mobile payment was lower than expected, which means that Taiwan's mobile payment services still have a lot of room for growth. Slade *et al*. (2013) and Williams (2021) pointed out that consumers' perceived risk will have a negative impact on the intention of using mobile payment. In other words, various risk considerations are a major obstacle for consumers to adopting mobile shopping and mobile payment (Gros, 2016; Madan and Yadav, 2018). In order to understand the impact of perceived risk on consumers' adoption of mobile payment services and to further identify the key factors that can increase the penetration rate of mobile payment in Taiwan, this research used a literature review and expert questionnaires to identify key factors and applied AHP analysis to find the decision weights of these factors. In addition, this study uses Fuzzy AHP to analyze the moderate impact of perceived risk on other factors. The results of this study can be used as a strategic reference for mobile payment companies and the Taiwan government in promoting mobile payment services.

2. LITERATURE REVIEW

2.1 Mobile payment

Mobile payment is one of the modern technological revolutions and it has a dominant market position in both developing and developed countries (Humbani and Wiese, 2019).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

In addition, mobile payment is an innovative form of technology that replaces traditional cash payment (Shao, Zhang, Li, and Guo, 2019). Kim, Mirusmonov and Lee (2010) defined this service as any payment method that uses mobile devices and wireless technology to initiate, authorize and confirm the exchange of financial value in exchange for goods and services. Lu, Yang, Chau and Cao (2011) pointed out that mobile payment is a combination of multiple mobile technologies, which can provide consumers with the ability to complete financial transactions. In general, a consumer can set up credit cards, prepaid accounts, or bank account information in the payment applications (apps) of a mobile device in advance. After that, the consumer can use the mobile device to pay for various goods or services without using cash or a physical credit card.

2.2 Influential factors of Mobile Payment

Most of the research on mobile payment attempts to develop a research model to capture user behaviors based on the structure of the existing technology adoption framework (Pal, De', Herath, & Rao, 2019). UTAUT and TAM are the most commonly used models (Flavian, Guinalíu, and Lu, 2020; Pal *et al*., 2019) and have been verified in many mobile payment service adoption environments (Khalilzadeh, Ozturk, and Bilgihan, 2017; Park, Ahn, Thavisay, and Ren, 2019). TAM is one of the earliest and most influential research models to explain IT adoption behaviors of users (Davis, 1989). Many studies have proved the effectiveness of TAM in IT adoption behavior research (Ramos de Luna, Liébana-Cabanillas, Sánchez-Fernández, and Muñoz-Leiva, 2019) and it is widely used in general information system research (Kim *et al*., 2010). TAM is an early attempt at applying psychological factors to information systems and computer adoption. The model believes that the usefulness and ease of use perceived by an individual are the attitude factors that determine the adoption of a particular technology and thus determine the usage intention that leads to the adoption of the technology (Davis, 1989). Venkatesh *et al*. (2003) synthesized some elements of eight behavioral intention models in the field of technology acceptance, including TAM and then proposed the UTAUT model. The purpose of UTAUT is to explain the user's intention to use the information system and its subsequent use behavior. The theory believes that four key constructs (performance expectations, effort expectations, social influence and facilitating conditions) are the direct determinants of usage intentions and behaviors. The perceived ease of use and perceived usefulness in TAM are renamed as effort expectations and performance expectations in UTAUT (Pal *et al*., 2019).

Some mobile payment adoption studies also consider combining multiple classic models in the construction and development process. Shin (2010) pointed out that combining UTAUT and TAM models will be able to better explain the acceptance and

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

use of mobile payment services. Among the many research constructs of mobile payment adoption behaviors, perceived ease of use and perceived usefulness are the most frequently used constructs, followed by perceived risk and social influence (Pal *et al*., 2019). In order to explore the impact of perceived risk on consumers' adoption of mobile payment, this study reviewed the mobile payment literature and adopted the perceived ease of use, perceived usefulness, social influence, facilitating condition and perceived risk as the research framework.

2.2.1 Perceived risk

In the past research on mobile payment, perceived risk has always been the main factor in the adoption and use of mobile payment (Pal *et al*., 2019). It is also an important concept that cannot be ignored (Rakhi & Mala, 2014). Mobile payment services are becoming more and more popular because they provide users with convenient transaction methods. However, in the era of increasingly rampant cybercrime, mobile payment transactions may have the risk of financial and data loss. Therefore, understanding how risks affect users' intentions to use mobile payment has become critical (Pal, Herath, De, and Rao, 2020). Park, Amendah, Lee and Hyun (2019) defined perceived risk as users' security concerns in the process of mobile payment transactions. Shao *et al*. (2019) pointed out that mobile payment users are prone to financial and privacy theft, as well as financial losses due to transaction failures and security failures. In the related research on perceived risk and mobile shopping, Thakur (2016), Chopdar and Sivakumar (2019) conceptualized the structure of perceived risk as security risk, privacy risk and financial risk.

Pal *et al*. (2020) defined security risk as a risk caused by lack of adequate security mechanisms or vulnerabilities in security mechanisms. When consumers adopt mobile payment services, they care about whether they have sufficient identity verification and security protection mechanisms in the transaction process to ensure that the transaction process is carried out in a safe state. Pal *et al*. (2020) pointed out that although mobile payment services can provide various security layers, including biometric passwords, regular updates of applications with the latest security features, adequate notifications and failure support, there is a huge gap in the security measures of most mobile applications, which leads to risks in transactions. The National Development Council (NDC Taiwan, 2020) pointed out that the penetration rate of mobile payment in Taiwan may be affected by users' security concerns.

Privacy risk is defined as personal loss due to the use of mobile payment that may expose personal information (Rana, Luthra, and Rao, 2018). Further, mobile payment is a behavior of payment through mobile devices. The transaction process may send relevant

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

financial information including credit card number, bank account, transaction amount, transaction time, etc., which all involve user privacy (Roca, Garcia, and de la Vega, 2008). In addition, consumers store personal information on various mobile payment application platforms, which increases the risk of hackers' attacks and frauds (Humbani & Wiese, 2019). Gao, Waechter and Bai (2015) found that privacy and security issues have a negative impact on the trust and satisfaction of mobile shoppers.

Pal *et al*. (2020) defined financial risk as a risk of potential monetary loss due to malfunctions, theft and transaction issues. In other words, financial risks include possible actual financial losses caused by the leakage of bank account numbers, passwords and credit card information. It also includes the possibility of financial losses caused by transaction failures and errors (de Kerviler, Demoulin, and Zidda, 2016). Meanwhile, due to the increasing number of mobile malware attacks in recent years, financial risk has become one of the most concerning factors in perceived risk. Pal *et al*. (2020) pointed out that risk is a strong negative influence on the intention of use and it is necessary to take good security measures to prevent financial risks.

2.2.2 Perceived usefulness

Perceived usefulness is defined as the degree to which a person believes that adopting the system will improve his/her work performance (David, 1989). Many studies have shown that when users find that mobile payment systems are useful for their transaction needs or financial problems, they will use mobile payment systems (Kim *et al*., 2010). The biggest advantage of mobile payment over traditional payment methods is its convenience because consumers can use their portable mobile devices to complete payments, which highlights the usefulness of this technology (Flavian *et al*., 2020; Shao *et al*., 2019). Kim *et al*. (2010) addressed that convenience has a positive impact on users' perception of the usefulness of mobile payment and it is considered to be one of the most important factors for users to adopt mobile payment services (Gao & Waechter, 2017; Kaur *et al*., 2020). Transaction speed is another important factor for consumers to adopt mobile payment (Dahlberg, Mallat, Ondrus, and Zmijewska, 2008). Mobile payment is an alternative to many payment methods. When consumers use mobile payment services, they can increase transaction speed and save time. Therefore, the increase in transaction speed makes consumers perceive that mobile payment is useful (Khalilzadeh *et al*., 2017; Schierz, Schilke, and Wirtz, 2010). Another advantage of mobile payment is that consumers have more transaction flexibility. That is, when consumers use mobile payment, they can choose different payment sources in advance, including different credit cards, debit cards, or bank accounts. In addition, consumers can also choose different mobile payment service platforms. Therefore, the transaction flexibility of mobile payment allows

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

consumers to perceive the usefulness of mobile payment (Schierz *et al*., 2010). Flavian *et al*. (2020) pointed out that when people believe that technology can improve or bring benefits to daily life, they will find this technology useful. Hygiene is another major factor in adopting mobile payment because mobile payment is a contactless transaction method, which avoids direct contact between people (Rafdinal and Senalasari, 2021). Therefore, consumers may appreciate the benefits of hygiene and safety and realize that mobile payment is useful.

2.2.3 Perceived ease of use

Dahlberg, Guo and Ondrus (2015) pointed out that perceived ease of use is the most important and widely used factor in evaluating the adoption rate of mobile payment. Perceived ease of use is the degree to which a person believes that using a particular system would be free of effort (Davis, 1989). It is considered to be the most important construct that influences users' decisions to adopt new technology (Ramos de Luna *et al*., 2019). Kim *et al*. (2010) pointed out that in order to avoid the poor usage rate of mobile payment, the system should be easy to learn and easy to use. Today, most mobile payment platforms in Taiwan use payment apps on mobile devices for payment operations. Therefore, the user experience of mobile payment apps also reflects consumers' awareness of the ease of use of the mobile payment system.

The user's perceived ease of use in the mobile payment system contains many factors. For example, are mobile payment systems and applications easy to learn (Khalilzadeh *et al*., 2017)? Can users operate the mobile payment system clearly and easily (Khalilzadeh *et al*., 2017; Schierz *et al*., 2010)? In other words, the user interface of mobile payment systems and apps should be simple and easy to use. The operation process needs to be smooth and does not require too many skills. These factors will affect the user's decision whether to adopt or continue to use mobile payment services. Moreover, when consumers feel that mobile payment is easy to use and does not require much effort, they have higher expectations for obtaining the required performance (Venkatesh *et al*., 2012). In addition, The National Development Council (NDC Taiwan, 2020) and MIC (2020) pointed out that the stability of mobile payment platforms is an important factor affecting the adoption of mobile payment by Taiwanese consumers.

2.2.4 Social influence

Social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh *et al*., 2003). Koenig-Lewis, Marquet, Palmer and Zhao (2015) pointed out that mobile payment users are very sensitive to social influence and will consider their friends' expectations of their use of

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

the technology. Enterprises and technology providers observe that users' use and satisfaction with technology affect others. In other words, user recommendations will motivate or discourage other users from trying new technologies. Moreover, recommending technology to others is an upcoming trend and of great interest to users (Singh *et al*., 2020). Khalilzadeh *et al*. (2017) pointed out that if more friends use mobile payment, people are more likely to use mobile payment. In other words, the more people adopt a new technology or product, the more consumers will be willing to adopt the technology or product.

In the era of the digital economy, social media has been used to promote products and services in different industries (Alalwan, Rana, Dwivedi, and Algharabat, 2017; Kapoor, Tamilmani, Rana, Patil, Dwivedi, & Nerur, 2018). Consumers also interact with others and exchange opinions through social media to decide whether to use or stop using the application (Chopdar & Sivakumar, 2019). In addition, advertising on social media has a positive impact on consumer product adoption (Alalwan, 2018; Syawaluddin, Joni, and Erwin, 2019). On the other hand, mobile app stores and websites provide ratings and comments functions. Consumers can learn about other consumers' feedback on the application and the service through these ratings and comments (Malik, Shakshuki, and Yoo, 2020; Tavakoli, Zhao, Heydari, and Nenadić, 2018). Therefore, other consumers' comments on an app may influence the adoption decision of potential users.

2.2.5 Facilitating conditions

Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system (Venkatesh *et al*., 2003). In the mobile environment, the concept of facilitating conditions is regarded as a key determinant for the use of mobile services and plays an important role in the adoption of mobile payment by consumers (Molina-Castillo *et al*., 2020). Chopdar and Sivakumar (2019) confirmed that the availability of infrastructure and resources will positively affect users' intention to use mobile shopping applications.

In the past ten years, Taiwan's mobile network infrastructure and signal coverage were quite complete and it was common for people to use mobile phones to access the Internet through 4G mobile networks. Therefore, in recent years, the development of mobile payment providers has focused on increasing the penetration rate of stores and the integration of financial institutions. Mobile payment services involve many stakeholders, including financial institutions, mobile payment providers, merchants and consumers (Johnson, Kiser, Washington, and Torres, 2018). If the integration of these stakeholders is higher, the quality of mobile payment services will be better. Therefore, the more financial institutions and stores participating in mobile payment services, the greater the

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

convenience it will bring to consumers. Mobile payment can use many different technologies, such as Near Field Communication (NFC), QR code, SMS, etc. (Ramos de Luna *et al*., 2019; Singh *et al*., 2020). Therefore, the more types of technologies supported by the mobile payment platform, the more beneficial to consumers. Similarly, the types of transactions provided by each mobile payment platform may be different. Therefore, the more types of transactions supported by mobile payment platforms, the more convenient for consumers. These facilitating conditions will also increase consumers' willingness to adopt mobile payment.

3. RESEARCH METHODOLOGY

3.1 Research framework

This study uses the modified Delphi method to identify key factors and confirm their importance. This method has two stages. In the first stage, this study disclosed five main factors and nineteen sub-factors through a literature review. The operational definitions of main factors and sub-factors are shown in Table 1 and Table 2, respectively. In the second stage, this study takes an expert survey to confirm the importance of factors. Adler and Ziglio (1996) stated that when using the Delphi method, it is sufficient to invite 10 to 15 experts with continuous experiences in the research topic. This study invites 15 experts with continuous mobile payment experiences to participate in the survey. The fields of experts are mainly related to mobile payment industries, including information, telecommunications, financial industries, etc. The detailed background information of experts is shown in Table 3. After two rounds of expert questionnaires, the "advertising" factor was excluded. Based on this result, this study established the research framework of AHP (Figure 1).

3.2 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in 1971. It's mainly used in uncertain situations and decision-making problems with multiple evaluation criteria. The Analytic Hierarchy Process compares the factors in pairs and establishes a pairwise comparison matrix to obtain the weight of each factor. Saaty (1980) suggested using consistency index (C.I.) and consistency ratio (C.R.) to test the consistency of the matrix. Higher consistency means that the value of the matrix is acceptable. Generally, when C.R. $\leqq$ 0.1 and C.I. $\leqq$ 0.1 are set, the consistency test is considered passed. In addition, AHP surveys can be conducted with small samples. Melillo and Pecchia (2016) indicated that a sample size of 19 is acceptable in an AHP survey.

This study constructed an AHP questionnaire based on the research framework

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

(Figure 1). The questionnaire evaluation adopted the nine-point evaluation scale proposed by Saaty (Saaty, 1990). The respondents of this survey are 30 mobile payment users in Taiwan, these users have more than three years of experiences in using mobile payment continuously. Detailed background information of the respondents is shown in Table 4.

Table 1. The operation definition of five main factors.

Main factors	Operational definition(reference)
Perceived risk	User's security concerns in the mobile payment transaction process (Shin, 2010; Gao & Waechter, 2017; Park *et al*., 2019).
Perceived usefulness	The degree to which a person believes that using a particular system would enhance his or her job performance (Davis, 1989).
Perceived ease of use	The degree to which a person believes that using a particular system would be free of effort (Davis, 1989).
Social influence	The degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh, 2003).
Facilitating conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system (Venkatesh, 2003).

Table 2. The operation definition of nineteen sub-factors.

Main factors	Sub-factors	Operation definition (reference)
Perceived risk	Privacy risk	Consumers are concerned about the risk of personal privacy information leakage that may be caused by mobile payment (Chopdar & Sivakumar, 2019; Gros 2016).
	Security risk	Consumers are concerned about the risk of information security that may be caused by using mobile payment (Chopdar & Sivakumar, 2019; Gros 2016).
	Finance risk	Consumers are concerned about the risk of financial loss that may be caused by using mobile payment (Chopdar & Sivakumar, 2019; Gros 2016).
Perceived usefulness	Transaction speed	The processing speed of the mobile payment transaction process (Grover & Kar, 2020; Khalilzadeh *et al*., 2017; Williams, 2021).
	Transaction flexibility	Optional transaction method (e.g. credit card, debit card, bank account) (Rafdinal & Senalasari, 2021; Schierz *et al*., 2010; Williams, 2021).
	Convenience	Payment with the mobile phone is easy to use and saves time (Gao & Waechter, 2017; Kaur *et al*., 2020).
	Hygienic	The contactless transaction process of mobile payment is hygienic (Khanra *et al*., 2021; Rafdinal & Senalasari, 2021; Williams, 2021).
Perceived ease of use	User interface	The ease of use of the user interface of the mobile payment app (Shao *et al*., 2019; Tavakoli *et al*., 2018).
	System performance	The performance and response speed of mobile payment systems and apps (Johnson *et al*., 2018; Tavakoli *et al*., 2018).
	System stability	The stability of the mobile payment system and apps (Grover & Kar, 2020; MIC, 2020; Tavakoli *et al*., 2018).
	Customer service	Customer service quality of mobile payment service providers. (Liébana-Cabanillas *et al*., 2019; Raman & Aashish, 2021).
Social influence	Advertising	The degree of influence of advertising media on consumers' adoption of mobile payment (Alalwan, 2018; Syawaluddin *et al*., 2019).
	Relatives and Friends	The degree of influence of relatives and friends' recommendations on consumers' adoption of mobile payment (Singh *et al*., 2020; Venkatesh *et al*., 2012).
	Social media	The degree of influence of social media opinions on consumers' adoption of mobile payment (Alalwan *et al*., 2017; Grover & Kar, 2020; Kapoor *et al*., 2018).
	App's ratings and reviews	User's rating and reviews of mobile payment apps (Chopdar & Sivakumar, 2019; Grover & Kar, 2020; Malik *et al*., 2020).
Facilitating conditions	Integration	The number of financial institutions that support mobile payment and the payment tools that can be integrated (Johnson *et al*., 2018; MIC, 2020).
	Payment types	Types of transactions that can be paid by mobile payment (Johnson *et al*., 2018; Shao *et al*., 2019).
	Merchant penetration rate	The number of merchants supporting mobile payment (Johnson *et al*., 2018; MIC, 2020).
	Payment technology	The payment technology is used for mobile payment (e.g. QR code, NFC, SMS) (Johnson *et al*., 2018; Ramos de Luna *et al*., 2019; Singh *et al*., 2020).

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

Table 3. The interview experts' background.

No.	Expert's Industry	Age	Gender	Experience	Title	Education level
1	Information industry	46-50	Male	5 years	Senior Manager	Master's degree
2	Information industry	46-50	Male	2 years	Senior Engineer	Bachelor's degree
3	Information industry	41-45	Male	5 years	Consultant	Master's degree
4	Information industry	36-40	Male	2 years	Senior Engineer	Bachelor's degree
5	Telecommunications	41-45	Male	5 years	Senior Engineer	Master's degree
6	Telecommunications	41-45	Male	5 years	Senior Engineer	Master's degree
7	Financial industry	31-35	Male	5 years	Section Manager	Master's degree
8	Investment industry	55-	Male	5 years	CEO	Master's degree
9	Government	31-35	Female	5 years	Engineer	Master's degree
10	Education	31-35	Female	5 years	Teacher	Master's degree
11	Manufacturing	36-40	Female	5 years	Manager	Doctor's degree
12	Service industry	41-45	Male	5 years	CEO	Master's degree
13	Insurance industry	31-35	Female	2 years	Specialist	Bachelor's degree
14	Insurance industry	46-50	Female	2 years	Director	Master's degree
15	Medical industry	55-	Female	5 years	Director	Master's degree

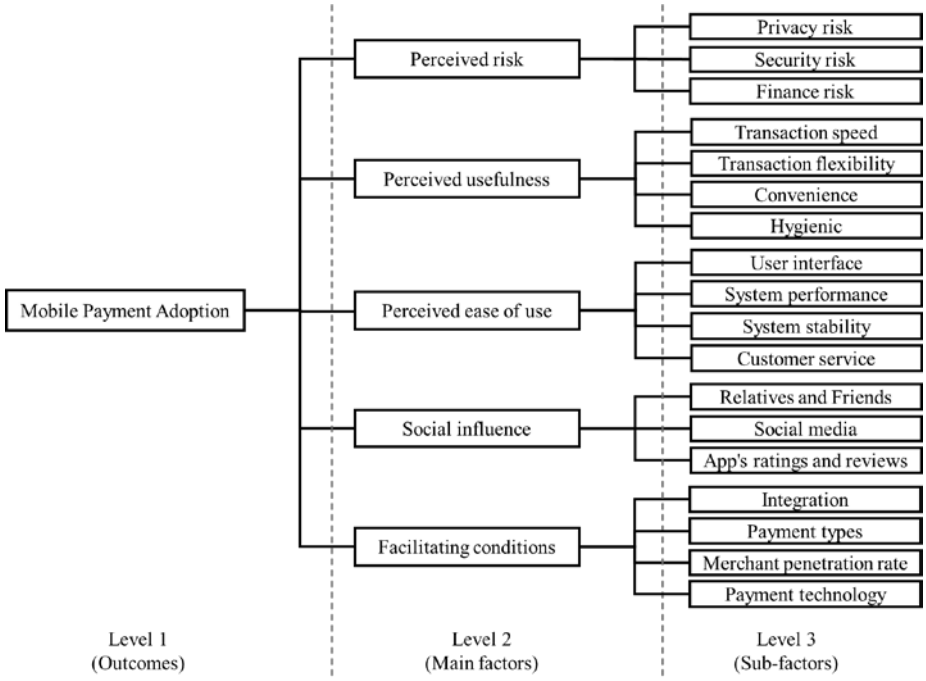


Figure 1. The research framework of AHP in this study

Table 4. The background of the respondents of the AHP survey.

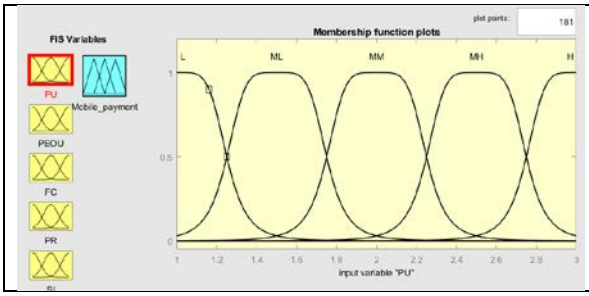
Attributes	Characteristics	Frequency	Ratio (%)
M-Payment experience	3 years	19	63.33%
	5 years	8	26.67%
	above 5 years	3	10.00%
Age	21-25 years	7	23.33%
	26-30 years	5	16.67%
	31-35 years	8	26.67%
	36-40 years	7	23.33%
	41-45 years	1	3.33%
	46-50 years	2	6.67%
Gender	Male	17	56.67%
	Female	13	43.33%
Educational level	Senior high school	1	3.33%
	Bachelor's degree	26	86.67%
	Master's degree	3	10.00%

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

3.3 Fuzzy set theory

The term fuzzy logic arose during the development of fuzzy set theory by Zadeh (1965). Laarhoven and Pedrycz (1983) used the concept of Fuzzy Theory to solve the problems of subjectivity, imprecision and ambiguity in the pairwise comparison of matrix values in traditional AHP. The method is to use the membership function to express the relative importance of the two factors. Li and Sun (2020) pointed out that Fuzzy AHP is widely regarded as one of the effective techniques for analyzing the weight distribution of decision factors and sub-factors. Therefore, this study adopts the Fuzzy AHP to further explore moderate effects among the factors of mobile payment adoption.

This study refers to the fuzzy rule-based procedures of Ly *et al*. (2018) and uses the MATLAB fuzzy toolbox to configure the inference system, membership function and IF-THEN rules described by Mamdani, as shown in Figure 2. In addition, this study uses high (H), medium-high (MH), medium-middle (MM), medium-low (ML) and low (L) values as input and output criteria to construct the IF-THEN rules. For example, IF-THEN rules involving mobile payment adoption decisions must include each combination of the 5 main factors of perceived risk (PR), perceived usefulness (PU), perceived ease of use (PEOU), facilitating conditions (FC) and social influence (SI). Since each factor has five values, there are 5x5x5x5x5=3125 rules, as shown in Table 5.



Range(Y)	Linguistic terms	values	Abbr.
2.6<Y<=3	High	3	H
2.2<Y<=2.6	Moderate-High	2.5	MH
1.8<Y<=2.2	Moderate Middle	2	MM
1.4<Y<=1.8	Moderate Low	1.5	ML
1.4<Y<=1.4	Low	1	L

Figure 2. Membership function and output interval ranges.

Table 5. An example of fuzzy rule-based calculations

Rules	Scenario	PU (*w*=0.333)	PEOU (*w*=0.321)	FC (*w*=0.142)	PR (*w*=0.127)	SI (*w*=0.077)	Output value	Linguistic term
1	if	H	H	H	H	H	3.00	H
2	if	H	H	H	H	MH	2.96	H
3	if	H	H	H	H	MM	2.92	H
…	if							
125	if	H	H	L	L	L	2.31	MH
…	if							
3125	if	L	L	L	L	L	1.00	L

4. RESULT ANALYSIS

4.1 AHP analysis

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

This study conducted a questionnaire survey on 30 mobile payment users in Taiwan and used AHP statistical software Expert Choice 2000 and Excel to analyze the main factors, the local weight and global weight of the sub-factors. The analysis results are shown in Table 6. The main weight (M*w*) of the main factors from high to low are perceived usefulness (M*w*=0.333), perceived ease of use (M*w*=0.321), facilitating conditions (M*w*=0.142), perceived risk (M*w*=0.127) and social influence (M*w*= 0.077). The results of the analysis show that the perceived risk weight is only ranked 4th, although experts generally agree that it's a necessary factor. On the other hand, the global weights (G*w*) of perceived risk sub-factors are privacy risk (G*w*=0.0504) ranked 8th, financial risk (G*w*=0.0467) ranked 9th and security risk (G*w*=0.0298) ranked only 14th. In addition, the top six sub-factors are system stability (G*w*=0.1233), convenience (G*w*=0.1162), transaction speed (G*w*=0.0992), user interface (G*w*=0.0889), transaction flexibility (G*w*=0.0839) and system performance (G*w*=0.0732). It is worth noting that the top six sub-factors belong to the factors of perceived usefulness and perceived ease of use.

Table 6. AHP weights and the ranking of main factors and sub-factors.

Main factors	Main weight(M*w*)	Main ranking	Sub-factors	Local weight(L*w*)	Local ranking	Global weight(G*w*)	Global ranking
Perceived risk	0.127	4	Privacy	0.397	1	0.0504	8
			Security	0.235	3	0.0298	14
			Finance	0.368	2	0.0467	9
Perceived usefulness	0.333	1	Transaction speed	0.298	2	0.0992	3
			Transaction flexibility	0.252	3	0.0839	5
			Convenience	0.349	1	0.1162	2
			Hygienic	0.101	4	0.0336	12
Perceived ease of use	0.321	2	User interface	0.277	2	0.0889	4
			System performance	0.228	3	0.0732	6
			System stability	0.384	1	0.1233	1
			Customer service	0.111	4	0.0356	11
Social influence	0.077	5	Relatives and Friends	0.247	3	0.0190	17
			Social media	0.390	1	0.0300	13
			App's ratings and reviews	0.363	2	0.0280	16
Facilitating Conditions	0.142	3	Integration	0.201	3	0.0285	15
			Payment types	0.281	2	0.0399	10
			Merchant penetration rate	0.402	1	0.0571	7
			Payment technology	0.116	4	0.0165	18

C.I.(0.003)<0.1, C.R.(0.003)<0.1

4.2 Fuzzy AHP analysis

To gain insight into the impact of perceived risk on consumer adoption of mobile payments, this study uses Fuzzy AHP and MATLAB R2022a software to explore the moderate impact between factors. Firstly, this study analyzes the influence of sub-factors on perceived risk. Secondly, it analyzes the mediating effect between perceived risk and each main factor. The 3D fuzzy surface analysis and observations among the sub-factors

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

of perceived risk are shown in Table 7. The moderate influence analysis between perceived risk and each main factor is presented in Tables 8 and Table 9.

Table 7. 3D fuzzy surfaces analyses of perceived risk sub-factors.

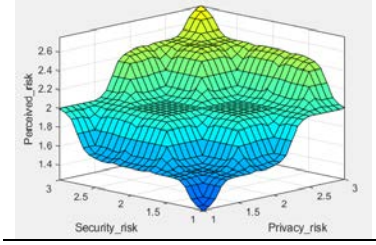
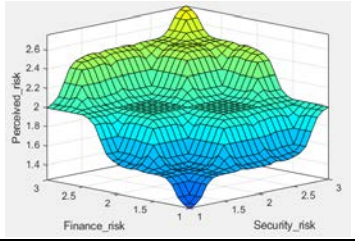
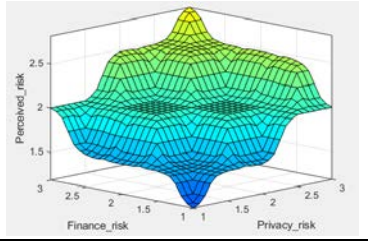
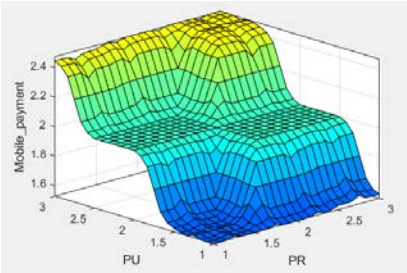
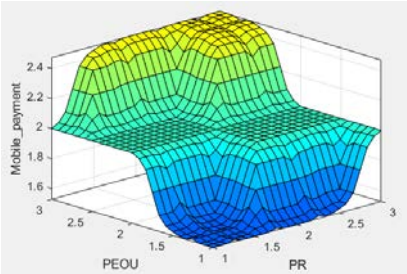
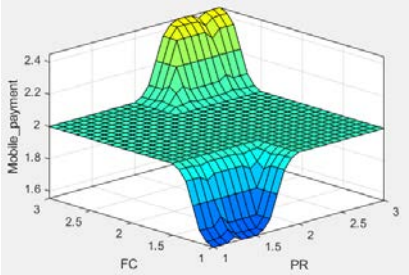
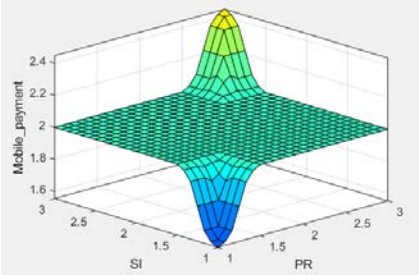
Privacy risk vs. Security risk	Security risk vs. Finance risk	Privacy risk vs. Finance risk
		
· Privacy risk has a higher impact on perceived risk than security risk. · When privacy risk is compared with security risk, it is clear that the impact of the two on perceived risk is positively correlated. · Implication: Privacy risk and security risk have additive effects on perceived risk.	· Finance risk has a higher impact on perceived risk than security risk. · When security risk is compared with finance risk, it is clear that the impact of the two on perceived risk is positively correlated. · Implication: Finance risk and security risk have additive effects on perceived risk.	· Privacy risk has a higher impact on perceived risk than finance risk. · When privacy risk is compared with finance risk, it is clear that the impact of the two on perceived risk is positively correlated. · Implication: Privacy risk and Finance risk have additive effects on perceived risk.

Table 8. 3D fuzzy surfaces analyses of main factors (I).

Perceived risk vs. Perceived usefulness	Perceived risk vs. Perceived ease of use
	
· Perceived usefulness has a significantly greater impact on decision-making than perceived risk. · When perceived risk increases from L to MM level, the impact of perceived usefulness on decision-making increases relatively. When the perceived usefulness reaches above MM, the effect of perceived risk above MM on decision changes little. When the perceived usefulness reaches above MH, perceived risk has little effect on decision-making. · Implications: As the importance of perceived risk increases, the impact of perceived usefulness on decision decreases (Note 1). However, when the importance of perceived usefulness reached a moderate level, the impact of perceived risk above moderate did not change much in the decision. When perceived usefulness reaches a high level, perceived risk has little impact on decision-making.	· Perceived ease of use has a higher impact on decision-making than perceived risk. · When perceived risk increases from L to MM level, the impact of perceived ease of use on decision-making increases relatively. · When perceived ease of use above MM, the effect of perceived risk above MM on decision-making changes little. · When the perceived ease of use above MH, the impact of perceived risk above the ML level on the decision-making changes little. · Implications: Perceived risk from medium-low to medium-high levels reduces the impact of perceived ease of use on the decision (Note 1). However, when the perceived ease of use reaches a high level, the impact of perceived risk above the medium-low level on the decision no longer increases.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

Table 9. 3D fuzzy surfaces analyses of main factors (II).

Perceived risk vs. Facilitating conditions	Perceived risk vs. Social influence
	
• When perceived risk is compared with facilitating condition, facilitating condition increases the influence on decision-making from the L level and perceived risk increases the influence on decision-making from the ML level. However, the influence on decision-making rose to the MH level only when the perceived risk was above the MM level and the facilitating conditions was above the MH level. • Implications: perceived risk from ML to MH will relatively weaken (note1) the impact of facilitating conditions on the decision. However, under high facilitating conditions, the impact of high perceived risk on decision-making does not change much.	• When perceived risk is compared with social influence, it is clear that perceived risk and social influence the decision at the beginning. However, the influence on decision-making is only elevated to MH level if both are above MH level. • Implications: Perceived risk is a negative factor that will relatively weaken the impact of social influence on decision-making.

(Note1: perceived risk is a negative factor)

5. CONCLUSIONS

In recent years, the popularity of mobile devices has led to the growth of mobile payment services. However, mobile payment still has challenges in consumer adoption and use. Many studies have found that perceived risk is a significant negative factor preventing users from adopting mobile payments. In order to understand the impact of perceived risk on consumers' adoption of mobile payment services and to further identify the key factors that can increase the penetration rate of mobile payment in Taiwan, this research used a literature review and expert questionnaires to identify five main factors and eighteen sub-factors, then applied AHP analysis to find the decision weights of these factors. In addition, this study uses Fuzzy AHP to analyze the moderate impact of perceived risk on other factors.

This study found that the users' decision weights on the main factors from high to low are the perceived usefulness, perceived ease of use, facilitating conditions, perceived risk and social influence. The top six sub-factors are system stability, convenience, transaction speed, user interface, transaction flexibility and system performance. These sub-factors belong to the factors of perceived usefulness and perceived ease of use, respectively. These decision-making behaviors may be related to the native use of mobile

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

payment. Because mobile payment is an alternative to traditional transaction methods, users often compare mobile payment with traditional payment methods. Therefore, alternatives should first be useful. Second, the user interface needs to be easy to use. Third, the facilitating conditions need to be sufficient. Perceived risk with a weight of 0.127 has the fourth highest impact on user decisions and its sub-factor privacy risk has the greatest impact on perceived risk. Therefore, in order to reduce users' concerns about mobile payment adoption, Taiwanese mobile payment service providers should strengthen the protection mechanism for users' privacy information.

To gain insight into the moderate impact of perceived risk on other main factors, this study conducted a Fuzzy AHP on three sub-factors of perceived risk and found that every two sub-factors had a significant additive effect on perceived risk. However, perceived risk is a negative factor, so higher importance of perceived risk may reduce the impact of another main factor on decision-making. On the other hand, the impact analysis between perceived risk and other main factors shows that perceived risk and each main factor have different degrees of additive influence on adoption decisions. In other words, when the weight of the main factor is higher, the additive influence of these two factors on the decision is greater. But two points are worth noting: 1. When the importance of perceived usefulness reaches a medium level, the effect of perceived risk above medium on adoption decisions does not change much. Furthermore, perceived risk has little effect on adoption decisions when perceived usefulness reaches a high level. 2. When the perceived ease of use reaches a high level, the impact of perceived risk above the medium-low level on the decision no longer increases. In other words, if mobile payment service providers enhance perceived usefulness and perceived ease of use, they can more effectively offset the negative impact of perceived risk. Therefore, this study suggests that mobile payment providers should strengthen the most important sub-factors of perceived usefulness and perceived ease of use to reduce the negative impact of perceived risk and increase the adoption of mobile payment services. The results of this study can provide a reference for the government and mobile payment providers in the promotion and business strategies of mobile payment services.

REFERENCES

[1] Adler, M. and Ziglio, E. (1996). Gazing into the oracle: the Delphi method and its application to social policy and public health. Jessica Kingsley Publishers.

[2] Alalwan, A. A. (2018). Investigating the impact of social media advertising features on customer purchase intention. *International Journal of Information Management*, 42, 65-77.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

[3] Alalwan, A. A., Rana, N. P., Dwivedi, Y. K., & Algharabat, R. (2017). Social media in marketing: a review and analysis of the existing literature. *Telematics and Informatics*, 34(7), 1177-1190.

[4] Chopdar, P. K., & Sivakumar, V. J. (2019). Understanding continuance usage of mobile shopping applications in India: The role of espoused cultural values and perceived risk. *Behaviour & Information Technology*, 38(1), 42–64.

[5] Dahlberg, T., Guo, J., & Ondrus, J. (2015). A critical review of mobile payment research. *Electronic Commerce Research and Applications*, 14(5), 265-284.

[6] Dahlberg, T., Mallat, N., Ondrus, J., & Zmijewska, A. (2008). Past, present and future of mobile payments research: a literature review. Electron. *Electronic Commerce Research and Applications*, 7(2), 165-181.

[7] Davis, FD. (1989). Perceived Usefulness, Perceived Ease of Use and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-340.

[8] de Kerviler, G., Demoulin, N. T.M., & Zidda, P. (2016). Adoption of instore mobile payment: Are perceived risk and convenience the only drivers? *Journal of Retailing and Consumer Services*, 31, 334-344.

[9] Ford, D., & Khan, A. (2019). *The Future of Commerce Payments in a Digital Society*. (ID: G00441515). Gartner Research.

[10] Flavian, C., Guinalíu, M., & Lu, Y. (2020). Mobile payments Adoption-introducing mindfulness to better understand consumer behavior. *International Journal of Bank Marketing*, 38(7), 1575-1599.

[11] Gao, L., & Waechter, K. A. (2017). Examining the role of initial trust in user adoption of mobile payment services: an empirical investigation. *Information Systems Frontiers*, 19 (3), 525-548.

[12] Gao, L., Waechter, K. A., & Bai, X. (2015). Understanding consumers' continuance intention towards mobile purchase: A theoretical framework and empirical study – A case of China. *Computers in Human Behavior*, 53, 249-262.

[13] Gros, M. (2016). Impediments to Mobile Shopping Continued Usage Intention: A Trust-Risk-Relationship. *Journal of Retailing and Consumer Services*, 33, 109-119.

[14] Grover, P., & Kar, A. K. (2020). User engagement for mobile payment service providers-introducing the social media engagement model. *Journal of Retailing and Consumer Services*, 53, 101718.

[15] Humbani, M., & Wiese, M. (2019). An integrated framework for the adoption and continuance intention to use mobile payment apps. *International Journal of Bank Marketing*, 37(2), 646-664.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

[16] Johnson, V. L., Kiser, A., Washington, R., & Torres, R. (2018). Limitations to the rapid adoption of m-payment services: understanding the impact of privacy risk on m-payment services. *Computers in Human Behavior*, 79, 111-122.

[17] Kapoor, K. K., Tamilmani, K., Rana, N. P., Patil, P., Dwivedi, Y. K., & Nerur, S. (2018). Advances in social media research: past, present and future. *Information Systems Frontiers*, 20, 531-558.

[18] Kaur, P., Dhir, A., Singh, N., Sahu, G., & Almotairi, M. (2020). An innovation resistance theory perspective on mobile payment solutions. *Journal of Retailing and Consumer Services*, 55. 102059.

[19] Khanra, S., Dhir, A., Kaur, P., & Joseph, R. P. (2021). Factors influencing the adoption postponement of mobile payment services in the hospitality sector during a pandemic. *Journal of Hospitality and Tourism Management*, 46, 26-39.

[20] Khalilzadeh, J., Ozturk, A. B., & Bilgihan, A. (2017). Security-related factors in extended UTAUT model for NFC based mobile payment in the restaurant industry. *Computers in Human Behavior*, 70, 460-474.

[21] Kim, C., Mirusmonov, M., & Lee, I. (2010). An empirical examination of factors influencing the intention to use mobile payment. *Computers in Human Behavior*, 26, 310-322.

[22] Koenig-Lewis, N., Marquet, M., Palmer, A., & Zhao, A. L. (2015). Enjoyment and social influence: predicting mobile payment adoption. *The Service Industries Journal*, 35(10), 537-554.

[23] Laarhoven, P. J. M. & Pedrycz, W. (1983). A Fuzzy Extention of Satty's Priority Theory. *Fuzzy Sets and System*, 11, 229-241.

[24] Li, R., & Sun, T. (2020). Assessing factors for designing a successful B2C E-Commerce website using fuzzy AHP and TOPSIS-Grey methodology. *Symmetry*, 12(3), 363.

[25] Liébana-Cabanillas, F., Japutra, A., Molinillo, S., Singh, N., & Sinha, N. (2020). Assessment of mobile technology use in the emerging market: Analyzing intention to use m-payment services in India. *Telecommunications Policy*, 44(9), 102009.

[26] Liébana-Cabanillas, F., Molinillo, S., & Montañez, M. R. (2019). To use or not to use, that is the question: Analysis of the determining factors for using NFC mobile payment systems in public transportation. *Technological Forecasting and Social Change*, 139, 266-276.

[27] Lin, W. R., Lin, C. Y., & Ding, Y. H. (2020). Factors Affecting the Behavioral Intention to Adopt Mobile Payment: An Empirical Study in Taiwan. *Mathematics*, 8(10), 1851.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

[28] Lu, Y., Yang, S., Chau, P. Y.K., & Cao, Y. (2011). Dynamics between the trust transfer process and intention to use mobile payment services: a cross-environment perspective. *Information & Management*, 48(8), 393-403.

[29] Ly, P.T.M., Lai, W. H., Hsu, C. W., & Shih, F. Y. (2018). Fuzzy AHP analysis of Internet of Things (IoT) in enterprises. *Technological Forecasting & Social Change*, 136, 1-13.

[30] Madan, K., & Yadav, R. (2018). Understanding and Predicting Antecedents of Mobile Shopping Adoption: A Developing Country Perspective. *Asia Pacific Journal of Marketing and Logistics*, 30(1), 139-162.

[31] Malik, H., Shakshuki, E. M., & Yoo, W. S. (2020). Comparing mobile apps by identifying 'Hot' features. *Future Generation Computer Systems*, 107, 659-669.

[32] Market Intelligence & Consulting Institute (MIC Taiwan). (2020), Mobile payment survey in the second half of 2020, Retrieved from https://mic.iii.org.tw/news.aspx?id=593 (Sept. 11, 2021).

[33] Melillo, P., & Pecchia, L. (2016). What is the appropriate sample size to run analytic hierarchy process in a survey-based research. *International Symposium on the Analytic Hierarchy Process(ISAHP) 2016 Proceedings*, 4-8.

[34] Molina-Castillo, F-J., López-Nicolás, C., Reuver, M, D. (2020). Mobile Payment: The Hiding Impact of Learning Costs on User Intentions. *Journal of Theoretical and Applied Electronic Commerce Research*, 15(1), 1-10.

[35] National Development Council (NDC Taiwan). (2020). *Relevant response measures for the domestic mobile payment penetration rate that has not yet reached the target* (special report).

[36] Pal, A., De', R., Herath, T., & Rao, H. R. (2019). A review of contextual factors affecting mobile payment adoption and use. *Journal of Banking and Financial Technology*, 3(1), 43–57.

[37] Pal, A., Herath, T., De, R., & Rao, H. R. (2020). Is the Convenience Worth the Risk? An Investigation of Mobile Payment Usage. *Information Systems Frontiers*. 23, 941-961.

[38] Park, J., Ahn, J., Thavisay, T., & Ren, T. (2019). Examining the role of anxiety and social influence in multi-benefits of mobile payment service. *Journal of Retailing and Consumer Services, 47*, 140-149.

[39] Park, J., Amendah, E., Lee, Y., & Hyun, H. (2019). M-payment service: interplay of perceived risk, benefit and trust in service adoption. *Human Factors and Ergonomics in Manufacturing*, 29(1), 31-43.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

[40] Rafdinal, W., & Senalasari, W. (2021). Predicting the adoption of mobile payment applications during the COVID-19 pandemic. *International Journal of Bank Marketing*, 39(6), 984-1002.

[41] Raman, P., & Aashish, K. (2021). To continue or not to continue: a structural analysis of antecedents of mobile payment systems in India. *International Journal of Bank Marketing*, 39(2), 242-271.

[42] Ramos de Luna, I., Liébana-Cabanillas, F., Sánchez-Fernández, J., & Muñoz-Leiva, F. (2019). Mobile payment is not all the same: The adoption of mobile payment systems depending on the technology applied. *Technological Forecasting & Social Change*, 146, 931–944.

[43] Rakhi, T. & Mala, S. (2014). Adoption readiness, personal innovativeness, perceived risk and usage intention across customer groups for mobile payment services in India. *Internet Research*, 24(3), 369-392.

[44] Rana, N., Luthra, S., & Rao, H. R. (2018). Developing a framework using interpretive structural modeling for the challenges of digital financial services in India. *PACIS 2018 Proceedings*, 53.

[45] Roca, J. C., Garcia, J. J., & de la Vega, J. J. (2008). The importance of perceived trust, security and privacy in online trading systems. *Information Management & Computer Security*, 17(2), 96-113.

[46] Saaty, T. L. (1980). The Analytic Hierarchy Process, McGraw-Hill.

[47] Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operation Research*, 48(1), 9-26.

[48] Schierz, P. G., Schilke, O., & Wirtz, B. W. (2010). Understanding consumer acceptance of mobile payment services: An empirical analysis. *Electronic Commerce Research and Applications*, 9(3), 209-216.

[49] Shao, Z., Zhang, L., Li, X. & Guo, Y. (2019). Antecedents of trust and continuance intention in mobile payment platforms: the moderating effect of gender. *Electronic Commerce Research and Applications*, 33, 100823.

[50] Shin, D. H. (2010). Modeling the interaction of users and mobile payment system: conceptual framework. *International Journal of Human-Computer Interaction*, 26(10), 917-940.

[51] Singh, N., Sinha, N., & Liébana-Cabanillas, F. J. (2020). Determining factors in the adoption and recommendation of mobile wallet services in India: Analysis of the effect of innovativeness, stress to use and social influence. *International Journal of Information Management*, 50, 191-205.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)

[52] Slade, E. L., Williams, M., & Dwivedi, Y. K. (2013). Mobile payment adoption: Classification and review of the extant literature. *The Marketing Review*, 13(2), 103-123.

[53] Syawaluddin, S., Joni, J., & Erwin, E. (2019). Influence of social media advertising, e-marketing and product quality on the process of purchasing nature cosmetics. *International Journal of Research in Business and Social Science*, 8(5), 316-321.

[54] Tavakoli, M., Zhao, L., Heydari, A., & Nenadić, G. (2018). Extracting useful software development information from mobile application reviews: A survey of intelligent mining techniques and tools. *Expert Systems with Applications*, 113, 186-199.

[55] Thakur, R. (2016). Understanding Customer Engagement and Loyalty: A Case of Mobile Devices for Shopping. *Journal of Retailing and Consumer Services*, 32, 151-163.

[56] Venkatesh, V., Morris, M. G., Hall, M., Davis, G. B., Davis, F. D., & Walton, S. M. (2003). User acceptance of information technology: toward a unified view. *MIS Quartely*, 27(3), 425-478.

[57] Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS Quartely*, 36(1), 157-178.

[58] Williams, MD. (2021). Social commerce and the mobile platform: Payment and security perceptions of potential users. *Computers in Human Behavior*, 115, 105557.

[59] Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*. 8(3), 338-353.

ISSN: 2304-1013 (Online); 2304-1269 (CDROM); 2414-6722 (Print)