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AN INTEGRATED TECHNOLOGY ACCEPTANCE MODEL FOR SMART CITY MOBILE APPLICATIONS: IDENTIFICATION OF KEY FACTORS AND EXTENSION OF TECHNOLOGY ADOPTION

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ABSTRACT

Smart cities have experienced significant improvements in service quality, resident satisfaction, sustainability, and economic development through the application of information and communication technology. With urban populations expected to grow, the adoption of smart city mobile applications (SCMA) can enhance the efficiency and impact of urban regions. This research explores the cognitive factors influencing user engagement and adoption of SCMA, by integrating identified factors with technological adaptation models. The decision of individual users to embrace such as SCMA has garnered attention from both information systems (IS) researchers and industry practitioners. Key factors affecting SCMA user acceptance include perceived enjoyment, innovation, trust, social influence, security, compliance, satisfaction, perceived benefit, ease of use, and intention to use. Data was analyzed using a structural equation model (SEM), with participants responding to questionnaire items on a five-point Likert scale. Out of an initial 1,142 responses, 1,062 valid samples were included in the final analysis after data filtering, achieving a response rate of 67 percent. Enhanced user satisfaction is crucial for the success of SCMA providers. The industry must allocate additional resources toward developing robust and reliable infrastructures and platforms that enhance mobility and service quality. To drive the future of Web 3.0, the industry must also address long-term challenges, such as creating new universal systems and environments. The conclusion of this study is discussed with respect to both theoretical and practical implications.

Keywords: Mobile application, smart city, smart systems, technology adoption, TAM.

INTRODUCTION

Tablet computers, smartphones, and other mobile devices have become essential communication tools (Dinh et al., 2013). In the context of smart cities, the focus has shifted towards mobile applications due to their widespread adoption and development. Cities around the world are increasing implementing smart city mobile applications (SCMA) to enhance urban living. Research and markets project that the global smart city market will reach $1.7 trillion by 2026, with a compound annual growth rate of 22.9%. Despite the growing interest in SCMA, challenges remain in their adoption and utilization. A study by Ma, Lam & Leung (2018) found that only 36 percent of respondents had used a smart city mobile application, and among those users, the frequency of use was relatively low. Understanding the factors that contribute to this low adoption and usage is essential for boosting SCMA effectiveness. Various studies have explored the factors affecting adoption of technology, leading to the development of frameworks such as the Technology Acceptance Model (TAM) by Davis (1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003). These models help identify the elements that influence users' attitudes and behaviors towards SCMA and suggest ways to enhance their acceptance and use. Given the potential of SCMA to enhance urban living, addressing the challenges in their adoption is essential. This study aims to empirically analyze SCMA acceptance by applying a model based on TAM. The goal is to identify key factors affecting SCMA adoption and propose strategies to overcome these challenges.

The adoption of specific technologies, such as smart city mobile applications, has attracted significant attention from both scholars and practitioners in information systems. Researchers often employ theoretical frameworks such as the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1977), the Theory of Planned Behavior (Ajzen, 1991) (TPB), the Diffusion of Innovations Theory (Rogers, 1995) (DIB), and the Technology Acceptance Model (TAM) (Davis, 1989) to investigate technology adoption. These concepts are based on a combination of customer perceptions and attitudes, which influence the adoption of technology within organizations.

Smart cities are becoming a trend, promising solutions to complex urban problems, such as traffic congestion, energy demands, waste management, and inadequate public services. Many major cities are leveraging the smart city concept, focusing on mobile application technologies and related infrastructures. However, there is no standardized approach for assessing the readiness to adopt SCMA technology in smart city development. Although previous studies have explored the intention to utilize and embrace smart city technologies, gaps remain in our understanding of this field. This study aims to assess the readiness and willingness of communities in the state of South Carolina to adopt SCMA. To achieve this, the study will employ structural equation model (SEM) in combination with TAM and related methodologies to evaluate user acceptance and motivation to adopt this technology.

Despite the rapid growth of smart cities in the mobile setting, research on how user perceptions shaped mobile application adoption is limited. Existing studies provide insufficient data on which aspects of the applications affect user satisfaction. Further, there is a significant disconnect between smart city mobile systems and the factors contributing to their success (Javed et al., 2022). This research seeks to evaluate how user attitudes towards SCMA services impact consumer perceptions and technology adoption. The attitudes investigated include: perceived entertainment, innovativeness, subjective norm, perceived security, perceived compatibility, satisfaction, perceived usefulness, perceived ease of use, and intention to use. This study introduces a novel approach by integrating these factors with TAM to create a new research paradigm. Structural equation modeling (SEM) will be used to determine the convergent validity, discriminant validity, and internal consistency of the proposed model (Hussain & Mubarik, 2021).

LITERATURE REVIEW

Mobile devices are portable gadgets that use wireless connections to provide voice, messaging and data services. Examples of mobile devices include smartphones, tablets, e-readers, handheld computers and portable music players. With the increasing adoption of Mobile services and devices, these tools significantly enhance citizen engagement and communication (Shahjehan et al., 2021). Mobile phones, being the most widely used ICT devices, have a global penetration rate exceeding 96 percent (Yfantis et al., 2013). Approximately three-quarters of the world's population use mobile phones, and spending on these devices has overtaken expenditure on other goods (Oghuma et al., 2012). It is estimated that by 2023, there will be over 6.4 billion mobile and broadband internet users (Ciupac-Ulici et al., 2023). The widespread use of mobile devices, which is critical for users and stakeholders in the digital age, facilitates easy access to mobile navigation apps. The rapid growth in the usage of mobile app and the internet is a key driver in the increased use of mobile devices. Research indicates that while people typically sleep between 8 to 10 hours a day, they spend about 5.5 hours daily on the Internet and mobile applications.

Smart Cities are urban areas that integrate information and communication technologies, energy systems, and transportation infrastructure. The term "smart city" emerged in the 1990s to describe such developments. According to the National Institute of Standards and Technology (NIST), a smart city is an urban environment that leverages advanced technology to improve residents' quality of life, boost economic development, and improve municipal services. The European Union defines a smart city as a space where conventional networks and services are upgraded through digital and communications technology to benefit both citizens and enterprises. Similarly, the International Telecommunication Union describes a "smart city" as a progressive metropolitan area utilizing ICT and other approaches, to enhance the quality of life, operational efficiency, and service delivery. There definitions reflect the integration of modern technology to address economic, social and environmental challenges for current and future generations. In this research, we adopt The NIST definition, focusing on how SCMA can enhance user experience and service accessibility (Tok & Chattopadhyay, 2023).

Upgrading essential infrastructure is crucial to fostering sustainable growth, improving resource efficiency, and enhancing the overall quality of life for urban populations. This is crucial for advancing intelligent urban environments. Smart cities offer numerous benefits, including increasing efficiency in public administration, integrating complex urban systems, managing numerous public services, reducing congestion in transit systems, and faster emergency response times (Ghazal et al., 2022). Smart city management involves interacting with data collected from various sources— such as mobile field workers, databases, photogrammetric images, and sensors. This data is utilized to manage urban infrastructure, respond to emergencies, and make instantaneous decisions by generating critical information quickly through active data management (Sağlam, 2014). In Türkiye, many metropolitan municipalities have developed mobile applications for iOS and Android devices that focus on areas such as transportation, water and sanitation, city guides, and tourism. The smart city framework encompasses a perception layer, a network layer, and an application layer. These layers work together to create a future urban environment that is more interconnected, measurable, and intelligent. A complete digital metropolis serves as the foundation of a smart city, enabling intelligent visualization and quantification of urban administration and operations. The Internet of Things (IoT) is created by attaching sensors to various objects, and integrating them with supercomputers and cloud computing (Ibrahim et al., 2020).

Various studies have highlighted the challenges faced by urban areas due to population growth and urbanization (Komninos, 2011; Mora, Deakin & Reid, 2018). In response, numerous smart city applications have been developed to address these challenges (Komninos, 2011; Kourtit et al., 2012). Modern smartphones, equipped with various sensors, computational and communication resources, are now capable of gathering physical world data (Adeel et al., 2023; Kourtit et al., 2012). SCMA are designed to tackle urban challenges and improve residents' quality of life (Bibri & Krogstie, 2017; Caragliu et al., 2011). To achieve the goal of creating a smart city, it is essential to integrate urban infrastructure with a variety of sensors, actuators, tag readers, and other sensing technologies across various sectors including structural, utility, transportation, environmental, governmental, and industrial. The technology deployment enables comprehensive monitoring and control of city systems (Caragliu et al., 2011; Komninos, 2011). By applying TAM developed by Hubert et al. (2017), this research aims to determine the factors that influence the adoption of SCMA. The study seeks to provide empirical insights to improve the design and implementation of these applications, thereby promoting the advancement of smart cities.

TAM is instrumental in understanding user perspective on SCMA, particularly for those who are new to these technologies. TAM has been applied across various research fields including mobile shopping (Hubert et al., 2017), electronic banking (Nor et al., 2010), online education (Jeong, 2011), virtual libraries (Zhao et al., 2015), electronic libraries (Zha et al., 2015), and mobile library services (Rafique et al., 2018). In the literature, TAM has been adopted and expanded with additional features for three main reasons (Fathema et al., 2015). This study aims to explore the cognitive factors influencing user attitudes toward SCMA. It investigates consumer technology adoption by employing frameworks that integrate customer beliefs and attitudes, which impact the adoption of information technology. In order to examine the convergent validity, discriminant validity, and internal consistency of the proposed model, the research will develop a novel framework using structural equation modeling (SEM). Previous studies have incorporated various components into TAM, such as perceived enjoyment, innovation, trust, social influence, security, compliance, satisfaction, perceived benefits, ease of use, and intention to use. This research will investigate how these factors affect individuals’ motivation to use SCMA (Hubert et al., 2017; Jeong, 2011). TAM is chosen as the theoretical framework for this study due to its effectiveness in understanding initial acceptance of technology especially in developing countries.

METHODOLOGY

User Acceptance Model of Smart City Mobile Applications

The Technology Acceptance Model (TAM) is grounded in two fundamental concepts: "perceived ease of use" and "perceived usefulness." According to Davis, "perceived ease of use" is defined as the degree to which an individual believes that utilizing a system will require minimal effort and be uncomplicated. Additionally, "perceived usefulness" refers to the degree to which an individual believes that the system will enhance their work performance (Davis, 1989, p. 320; Davis, 1993, p. 481). Davis (1989; 1993) first introduced these concepts in his seminal works. Numerous studies have extensively utilized the TAM paradigm to evaluate how people adopt various technologies and systems. Research consistently shows that the perceived ease of use and perceived usefulness significantly influence users' attitudes and intentions in adopting new technologies. Furthermore, users' attitudes and perceptions of an application's usefulness also have a substantial influence on their intention to use it.

The TAM framework has proven particularly effective in assessing user acceptance of new smartphone systems and technologies including mobile systems (Abu-Dalbouh, 2013; Park & Kim, 2014; Rafique et al., 2018), mobile learning (Huang et al., 2007; Park et al, 2012; Mugo et al., 2017), mobile banking (Mutahar et al., 2018), mobile library (Chen et al., 2017; Yoon, 2016; Park et al., 2014). TAM is also considered useful for studying the adoption of SCMAs. It is expected to reveal causal relationships similar to those identified in previous studies. This research employs a TAM-based approach to explore the relevance of various factors influencing SCMA user acceptance. The goal is to determine whether SCMA is accepted by users and to identify the key elements affecting its adoption.

Innovativeness

Personal innovativeness in information technology refers to an individual's readiness to explore and experiment with new technologies, as proposed by the innovation diffusion hypothesis (Agarwal & Prasad, 1998, p. 208; Rogers, 1995). Koivisto et al. (2016) suggests that this factor can help identify individuals who are more likely to adopt new technologies early in their implementation. Individuals' openness to adapting is often reflected in their level of innovativeness (Karahanna et al., 2002; Thatcher et al., 2003; Nov & Ye, 2008). In this study, TAM is integrated with other methodologies to investigate how various factors influence user acceptance of SCMA. Specifically, the study postulates that:

H_{1a}: Innovativeness towards SCMA positively influences perceived entertainment of SCMA.
H_{1b}: Perceived entertainment of SCMA positively influences satisfaction with SCMA.

Perceived Entertainment

In this study, "perceived entertainment value" refers to the enjoyment a user experiences when interacting with the SCMA. This concept is described by Davis (1993, p. 485) and is identified as a crucial factor in mobile app usage. Research into technology consumer behavior, including work by Eighmey and McCord (1998) has established entertainment value as an important component of user satisfaction. According to Huizingh (2000), perceived entertainment plays a crucial role in applying skills through technology in unique research contexts. This article extends TAM by exploring the relationship between enjoyment, perceived usefulness and user satisfaction in the context of SCMA. Specifically, we propose that:

H_{2a}: Perceived entertainment positively influences the perceived usefulness of the smart city mobile application.
H_{2b}: Perceived entertainment positively influences user satisfaction with the smart city mobile application.

Perceived Trust

Perceived trust typically refers to an individual's confidence in the reliability of a technology or system. According to Pavlou (2003), perceived trust involves the willingness of users to take risks when engaging in digital activities. As stated by Nash (2019), "perceived entertainment value" is defined as "the degree to which a user is delighted by the program" (p. 21). Researchers have identified entertainment as a crucial factor in mobile app usage. Eighey and McCord (1998) highlighted this in their exploration of satisfaction theory and its application to technology consumption, noting that entertainment value is a crucial component. Additionally, Huizingh (2000) emphasized the importance of this factor in effectively utilizing technology for innovative research. This article extends TAM by exploring the link between enjoyment, perceived usefulness, and pleasure within the context of SCMA. As a result, users' perceptions of a mobile application's trustworthiness significantly influence their usage intentions and behaviors. Thus, perceived trust is likely to have a substantial influence on a smart city mobile app's perceived usefulness. Based on this understanding, this study posits that:

H_{3a}: The perceived trust in a smart city mobile application is positively influenced by the degree to which trust is recognized.

Subjective Norm

While much research has reproduced and expanded TAM, the specific effects of each component, such as subjective norm, remain unclear. The concept of subjective norm refers to the belief that significant others expect an individual to either engage in or refrain from a particular behavior (Fishbein & Ajzen, 1977, p. 302; Bhatti & Ur Rahman, 2019). In essence, it represents an individual's perception of how influential people in their environment expect them to act (Moan & Rise, 2006, p. 719). Numerous studies have shown that subjective norms significantly impact various dependent variables (Cheung et al., 2002; Schepers & Wetzels, 2007); however, some studies have not found notable effects (Lau et al., 2001). In this context, subjective norm pertains to the extent to which users perceive pressure from significant others (Teo, 2010) to use the smart city mobile application. This study seeks to incorporate subjective norm into the model by examining how users perceive the expectations of key individuals regarding their use of SCMA. This element is anticipated to have a substantial influence on the perceived usefulness of the smart city mobile app. Therefore, this study hypothesizes that:

H_{4a}: Subjective norm positively influences the perceived usefulness of smart city mobile applications.

Perceived Compatibility

Compatibility refers to how well a new technology or system aligns with existing practices, user needs, and the environment (Karahanna et al., 2002). It encompasses the fit between system features and users' experiences, which is a crucial dimension of job compatibility (Rogers, 1995). Previous research has consistently identified compatibility as a key factor in the acceptance of new technologies (Chau & Hu, 2002; Liang et al., 2003; Taherdoost, 2018). Along with perceived value and ease of use, compatibility significantly influences the acceptance of new technology (Tornatzky & Klein, 1982). Following this, Agarwal and Prasad (1997) emphasized the importance of compatibility within TAM, while Taylor and Todd (1995) suggested its inclusion in TAM. This study anticipates that perceived compatibility will play a crucial role in the perceived usefulness of a smart city mobile application, as the model is improved by aligning with users' past experiences and values. Therefore, the following hypotheses are proposed:

H_{5a}: Perceived compatibility positively affects the intention to use a smart city mobile application.
H_{5b}: Perceived compatibility positively impacts the perceived ease of use of a smart city mobile application.
H_{5c}: Perceived compatibility positively influences the perceived usefulness of a smart city mobile application.

Perceived Security

According to Kalakota and Whinston (1997, p. 242), security involves the risk of harm to data from destruction, unauthorized disclosure, alteration, misuse, or waste. Research has extensively explored the importance of security considerations in digital environments. Godwin-Jones (2001) identified security concerns as a key obstacle to technology adoption and Park and Kim (2014) noted that security remains a significant challenge for using online services. In this study, "perceived security" refers to users' perception of their protection against potential security risks and their control over personal data in an online setting. Generally, perceived security refers to a user's belief that a system can reliably handle transactions while safeguarding personal information (Salisbury, Pearson, & Pearson 2001). This factor is expected to have a significant impact on the perceived usefulness of a smart city mobile app. Thus, the following hypotheses are proposed:

H_{6a}: Perceived security positively influences the intention to use smart city mobile applications.
H_{6b}: Perceived security positively impacts the perceived usefulness of smart city mobile applications.

Satisfaction

User satisfaction is commonly understood as a user's attitude toward a mobile system, representing an object-based attitude. Previous research has assessed satisfaction through various aspects, including specific systems, information, features related to mobile applications (Wixom & Todd, 2005). However, there is a complex relationship between user satisfaction and usage (Dinev & Hu, 2007). For an attitude to to predict behavior effectively, it must align with the behavior in terms of time, objective, and context. This research aims to explore how user satisfaction with SCMA influences their desire to use these applications. As a result of the inclusion of this component is expected to significantly impact the perceived usability of smart city mobile applications. Therefore, the study proposes that:

H_{7a}: User satisfaction positively affects the perceived intention to use smart city mobile applications.

Perceived Usefulness

Technology adoption models suggest that perceived usefulness significantly impacts users' attitudes toward and intentions to utilize specific information systems and services (Davis, 1985; Davis, 1989; Davis, 1993). Most research in this area has found that perceived usefulness positively influences behavioral intention (Joo, & Sang, 2013; Hamid et al., 2016; Amoako-Gyampah, 2007; Suki & Suki, 2011; Jamal & Sharifuddin, 2015). This study seeks to evaluate the perceived usefulness of SCMA for users and anticipates that it will similarly positively affect attitudes toward SCMA. Hence, it is proposed that:

H_{8a}: The perceived usefulness of a smart city mobile application positively influences the intention to use it.

Perceived Ease of Use

TAM developed by Davis (1985), has become a prominent framework in information systems research. Based on the Theory of Reasoned Action (TRA), TAM) explores the relationships between users' judgments of system ease of use, its usefulness, their attitudes, and their intentions to use the system (Davis, 1985). "Perceived ease of use" refers to the extent to which a user believes that interacting with a system requires minimal mental effort. Studies using TAM have shown that the perception of ease of use affects perceived usefulness (Venkatesh & Davis, 1996). This research aims to analyze how users' perceptions of a system's ease of use impact their intention to use it. Previous studies by Hamid et al. (2016), Ramayah and Ignatius (2005), and Moslehpour et al. (2018) support the investigation this effect. This component is expected to significantly influence the perceived user-friendliness of smart city mobile applications. Consequently, the following hypotheses are proposed:

H_{9a}: The perceived ease of use of a SCMA positively influences the intention to use it.
H_{9b}: Perceived ease of use positively influences the perceived usefulness of a smart city mobile application.

Structural Equation Modeling

Structural equation modeling (SEM) is a set of statistical methods used to analyze and shed light on the relationships between observed and latent variables. SEM provides a more rigorous alternative to traditional regression analysis by considering measurement error and analyzing linear causal relationships between variables. It is particularly effective for handling the intricacies associated with multiple regression analyses, by examining complex interrelationships among variables. The foundation of SEM lies in the formulation of hypotheses by researchers on the connections between specific measured variables, such as the acceptance of risky behaviors, and other quantifiable factors. In SEM diagrams, measured variables often called as observed, indicator, or manifest variables, are represented by squares or rectangles. However, latent variables, also known as constructs or unobserved variables, are depicted as circles or ovals. These latent variables are derived from multiple measurements. Arrows and lines ae used to represent the connections between variables, and the absence of a connecting line suggests that there is no direct linear relationship between the variables.

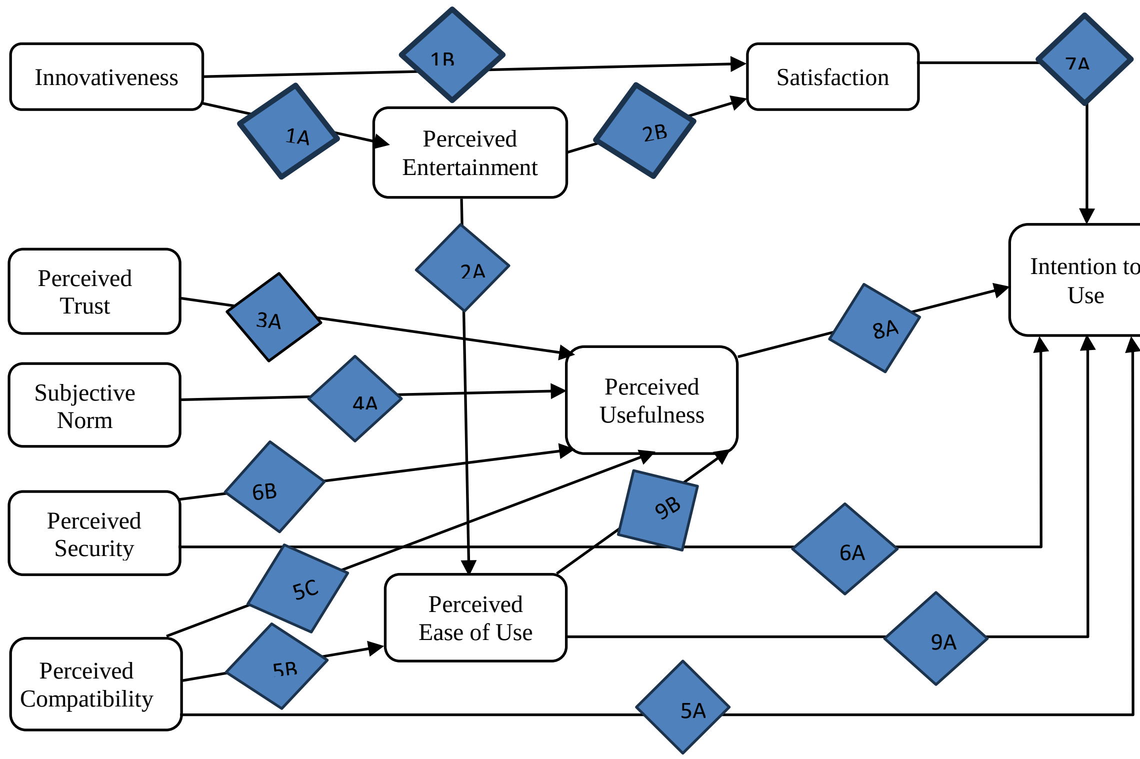
SEM allows for the estimation of latent variables from observed ones, accounting for measurement error in the process. This approach enables researchers to empirically test fully specified models within a conceptual or theoretical framework. The fit of these models to sample data can be rigorously evaluated, which helps in validating theoretical constructs. As an advanced statistical method, SEM typically needs a minimum sample size of 200 for analyzing basic models. More complicated models may demand even larger sample sizes to achieve sufficient statistical power. The model's fit is assessed before individual pathways are reviewed. Four key statistics are often used to assess model fit, including the Comparative Fit Index (CFI) and the Tucker Lewis index (TLI), which is also known as the Non-Normed Fit Index. A model is considered to fits the data adequately if the CDI and TLI values are 0.90 or higher. Finally, the root-mean residual value is examined, with values that are equal to or less than 0.08 indicating an acceptable model fit.

Research Model

In order to validate the presented hypotheses, the following research model (Figure 1) was tested.

Figure 1

The Proposed Research Model



Interviews were conducted to identify potential critical psychological issues related to the SCMA. The primary goals were to confirm factors identified in previous research, analyze various aspects of SCMA, identify specific target groups within budget constraints, and develop valid and reliable questionnaires.

Table 1

Items for Variables Understudy

Construct	Code	Item	Source
Perceived Entertainment	ENJ1	The process of using the smart city mobile application is enjoyable.	(Lu & Su, 2009)
	ENH2	I experience pleasure while accessing the smart city mobile application.	(Lu & Su, 2009)
	ENJ3	Overall, I find visiting the smart city mobile application to be fun.	
Innovativeness	INN1	I am usually aware of the smart city mobile application before others.	(Kim et al., 2010; Leong et al., 2013)
	INN2	I am often one of the first to try the smart city mobile application.	
	INN3	New smart city mobile applications excite me	
	INN4	I enjoy experimenting with new ways of doing things	
Perceived Trust	TRS1	I trust the smart city mobile application systems to be reliable.	(Chandra et al, 2010; Gefen, 2000; Jarvenpaa et al, 1999)
	TRS2	I consider smart city mobile application systems to be secure.	
	TRS3	I perceive the smart city mobile application systems as trustworthy.	
	TRS4	I have confidence in the reliability of smart city mobile application systems.	

(continued)

Construct	Code	Item	Source
	TRS5	I trust that smart city mobile application systems will functions accurately, even without monitoring.	
Subjective norm	SN1	People who significantly influence me believe I should use the smart city mobile application.	(Schneider, 1999, Venkatesh & Davis, 2000; Taylor & Todd, 1995)
	SN2	People who are important to me think I should use the smart city mobile application.	
	SN3	Most of the influential individuals in my life would support my use of the smart city mobile application.	
Perceived Security	SEC1	The probability of unauthorized third-party surveillance during payment processes is very low.	(Schneider, 1999, Luarn & Lin, 2005; Parasuraman et al, 2005)
	SEC2	The likelihood of misuse of information, such as business partner names or payment amounts, is minimal when using the smart city mobile application services.	
	SEC3	The risk of unauthorized use of billing information (e.g. credit card or bank account details) is very low when using smart city mobile application.	
	SEC4	I find smart city mobile application services dependable for conducting financial activities.	
Perceived Compatibility	COM 1	Using smart city mobile application services fits well with my lifestyle.	(Schneider, 1999; More & Benbasat, 1991; Plouffe et al., 2001)
	COM 2	Employing smart city mobile application services aligns with my preferred purchasing methods of products and services.	
	COM 3	I would prefer using smart city mobile application services over other payment methods (e.g., credit card, cash).	
Satisfaction	SAT1	I am satisfied with my experience using smart city mobile application	(Lin et al., 2010; Gumussoy & Yeterel, 2016; Fang et al., 2011)
	SAT2	The smart city mobile application offers a pleasant experience.	
	SAT3	Overall, I am satisfied with the smart city mobile application experience	
Perceived Usefulness	PUS1	Smart city mobile application services are a useful tool for city life	(Schneider, 1999; Bhattacherjee, 2001; Deveraj et al., 2002; Van der Heijden, 2003)
	PUS2	Using smart city mobile application services help manage urban life efficiently.	
	PUS3	Smart city mobile application services improve efficiency of mobile application usage.	
	PUS4	Employing smart city mobile application services expands my consumer choices.	
Perceived Ease of Use	EOU1	Learning to use smart city mobile application services is easy.	(Schneider, 1999; Bhattacherjee, 2001; Venkatash & Davis, 2000; Davis, 1989; Taylor & Todd, 1995)
	EOU2	Interactions with smart city mobile application services are clear and understandable.	
	EOU3	Completing the necessary steps to use smart city mobile application services is simple.	
	EOU4	Engaging with smart city mobile application services is easy.	
Intention to Use	INT1	Given the opportunity, I will use smart city mobile application services.	(Schneider, 1999; Gefen, 2000; Venkatash & Davis, 2000; Davis, 1989)
	INT2	I am inclined to use smart city mobile application services soon.	
	INT3	I want to use smart city mobile application services soon.	
	INT4	I intend to use smart city mobile application services when the opportunity arises.	

College students were chosen for the interviews due to their adeptness with technology. Participants were recruited from six public universities in Ankara and Konya (Rosen et al., 2013). Moreover, university students are considered a representative sample of general smartphone application users (Shin & Shin, 2011; Hargittai, 2007). The survey items were meticulously selected from studies that are highly regarded in the literature (Table 1). The selection was based on the psychometric features of the instruments, including reliability, validity, and the capacity to reliably assess relevant constructs. These studies are recognized for their rigorous methodology, comprehensive theoretical grounding, and empirical support. The selected items have consistently shown high internal consistency, construct validity, and predictive validity, ensuring they effectively capture the intended constructs in the context of SCMA.

Table 2

Internal Reliability and Convergent Validity

Factor	Item	Cronbach's Alpha	Item-Total Correlation	Factor Loading	Mean	Standard Deviation	Average Variance Extracted	Composite Reliability
Perceived Entertainment	ENJ1	0.935	0.896	0.896	3.26	1.035	0.847	0.943
	ENH2		0.937	0.937	3.17	1.03		
	ENJ3		0.927	0.927	2.92	1.04		
Innovativeness	INN1	0.941	0.793	0.81	2.3729	1.03843	0.746	0.897
	INN2		0.785	0.885	3.9068	1.04026		
Perceived Trust	TRS1	0.951	0.833	0.833	3.73	0.961	0.741	0.896
	TRS2		0.876	0.876	3.72	0.983		
	TRS3		0.873	0.873	3.7	0.955		
	TRS4		0.884	0.884	3.67	0.965		
Subjective Norm	SN1	0.924	0.923	0.923	3.67	0.956	0.818	0.931
	SN2		0.901	0.901	3.69	0.918		
	SN3		0.889	0.889	3.73	0.896		
Perceived Security	SEC1	0.961	0.873	0.873	3.21	1.015	0.782	0.915
	SEC2		0.885	0.885	3.28	1.02		
	SEC3		0.895	0.895	3.29	1.046		
	SEC4		0.79	0.79	3.49	0.938		
Perceived Compatibility	COM1	0.957	0.76	0.76	3.86	0.957	0.637	0.84
	COM2		0.73	0.84	3.79	0.94		
	COM3		0.703	0.793	3.82	0.944		
Satisfaction	SAT1	0.948	0.75	0.75	3.73	0.917	0.645	0.834
	SAT2		0.711	0.711	3.81	0.9		
	SAT3		0.71	0.71	3.82	0.888		
Perceived Usefulness	PUS1	0.951	0.707	0.807	4.07	0.95	0.725	0.858
	PUS2		0.739	0.839	4.07	0.935		
	PUS3		0.719	0.819	4.02	0.952		
	PUS4		0.773	0.773	3.96	0.937		
Perceived Ease of Use	EOU1	0.917	0.91	0.91	3.93	0.939	0.832	
	EOU2		0.942	0.942	3.94	0.918		
	EOU3		0.884	0.884	3.97	0.9		
	EOU4		0.802	0.802	3.99	0.952		
Intention to Use	INT1	0.917	0.768	0.768	4.01	0.891	0.648	

(continued)

Factor	Item	Cronbach's Alpha	Item-Total Correlation	Factor Loading	Mean	Standard Deviation	Average Variance Extracted	Composite Reliability
	INT2		0.858	0.858	3.77	1.092		
	INT3		0.787	0.787	3.99	0.893		
	INT4		0.891	0.891	3.89	0.951		

After the interview with the subject matter expert, the primary text data and responses from the participants were used to develop the final set of questionnaire items for the primary survey (Zaki et al., 2019). The wordings and descriptions of the questionnaire items were then reviewed and revised as needed. To assess the reliability of the items, Cronbach's alpha coefficients were calculated. All items showed values greater than the recommended threshold of 0.70, as established by Hair et al. (1998) as shown in Table 2.

To address potential non-response bias, several measures were implemented. Data collection was conducted between March and July 2020, with an initial target sample size of over 1,000 respondents to ensure statistical significance and sufficient power for inferential analyses. Surveys were administered both online and in paper form, targeting a diverse group of users with varying levels of experience with SCMA. Clear eligibility criteria were established to ensure data quality: respondents had to be at least 18 years old, have access to a mobile device, have used a smart city mobile application within the past six months, and be willing to complete the survey fully. After filtering out incomplete or inconsistent responses, the final sample consisted of 1,062 valid responses. Using multiple survey modes helped improve accessibility and response rates, while filtering responses for completeness and consistency further enhanced data quality. This approach effectively addressed potential non-response bias, ensuring reliable and robust results.

Table 3

Statistics of Factors

Statistic	N	Standard deviation	Mean	Skewness	Kurtosis
Perceived Entertainment	1062	2.8544	2.8544	0.119	-0.231
Innovativeness	1062	3.0946	3.0946	-0.377	0.752
Perceived Trust	1062	2.4365	2.4365	0.746	0.851
Subjective norm	1062	2.2687	2.2687	0.864	1.086
Perceived Security	1062	2.6751	2.6751	0.152	0.043
Perceived Compatibility	1062	2.1601	2.1601	0.846	0.846
Satisfaction	1062	2.182	2.182	0.757	0.629
Perceived Usefulness	1062	1.9397	1.9397	1.018	1.231
Perceived Ease of Use	1062	2.0353	2.0353	0.71	0.234
Intention to Use	1062	2.0829	2.0829	0.862	0.928

The study sample was diverse, consisting of both male (46.2%) and female (53.8%) respondents, all between the ages of 18 and 29. A sizeable proportion of the participants reported daily use of SCMA, reflecting their high level of familiarity and engagement with technology. The sample also included individuals who used the service on a weekly or monthly basis, among other usage patterns. For data analysis, SPSS version 24.0 was used to generate descriptive statistics for each concept, making the data more accessible and comprehensive. Internal reliability and convergent validity were assessed via factor loadings and average variance extracted (AVE) values. both of which were studied. The measurement model satisfied the requirements for both reliability and validity, with factor loadings exceeding 0.70 and AVE values greater than 0.50, as shown in Table 3.

Discriminant validity as defined by Fornell and Larcker (1981) is achieved when the correlation between two constructs is smaller than the square root of the average variance extracted (AVE) for each construct. This criterion was used to determine discriminant validity in the current study. The measurement model demonstrated strong discriminant validity, as evidenced by the findings presented in Table 2.

RESULTS

Confirmatory factor analysis (CFA) was conducted to assess both the measurement model and the proposed research model. Table 3 provides the descriptive statistics for each variable included in the analysis. The observed averages, ranging from 1.93 to 3.09, show that consumers generally have a positive view of the smart city mobile application (SCMA). Several indices were utilized to evaluate the fit of the model including the Chi-square to degrees of freedom ratio (χ^2/df), the Standardized Root Mean Square Residual (SRMR), the Goodness-of-Fit Index (GFI), the Normed Fit Index (NFI), the Adjusted Goodness-of-Fit Index (AGFI), the Root Mean Square Error of Approximation (RMSEA), and the Comparative Fit Index (CFI). The results from these indices indicated that both the measurement model and the proposed research model showed a fair fit as demonstrated by the findings.

Table 4

Measurement Model

Fit index	Measurement Model	Recommended value	Source
X^2/df	2.014	<5.00	(Shin & Shin, 2011)
GFI	0.906	>0.90	(Bagozzi & Yi, 1988)
AGFI	0.884	>0.80	(Fornell & Larcker, 1981)
RMSEA	0.064	<0.06	(Jöreskog & Sörbom 1996)
SRMR	0.031	<0.08	(Bagozzi & Yi, 1988)
NFI	0.912	>0.90	(Bentler & Bonett, 1980)
CFI	0.953	>0.90	(Fornell & Larcker, 1981)
IFI	0.954	>0.90	(Widaman & Thompson, 2003)

Table 5 shows that both models' statistical metrics were satisfactory. The findings, as shown in Table 5 and Figure 2, supported all of the study model's hypotheses.

H_{1a}, b = 0.632, CR = 8.042, p 0.001
H_{1b}, b = 0.999, CR = 9.647, p 0.001

Showed substantial beneficial impacts on perceived entertainment and satisfaction. Similarly, perceived utility was affected by perceived enjoyment.

H_{2a}, b = 0.114, CR = -2.72, p 0.001

Furthermore, contentment was negatively affected by perceived entertainment.

H_{2b}, b = -0.125, CR = -2.288, p 0.001

Perceived compatibility influenced perceived ease of use and usefulness in a substantial way.

H_{5b}, b = 0.722, CR = 12.468, p 0.001
H_{5c}, b = 0.47, CR = 6.199, p 0.001
H_{5c}, b = 0.47, CR = 6.199, p 0.001

Intention to use and perceived usefulness were both positively influenced by perceived ease of use.

H_{9a}, b = 0.05, CR = 8.899, p 0.001
H_{9b}, b = 0.467, CR = 8.899, p 0.001
H_{9b}, b = 0.467, CR = 8.899, p 0.001

In comparison to other criteria, perceived ease of use had the greatest impact on intention to use, while perceived entertainment had the least.

Table 5

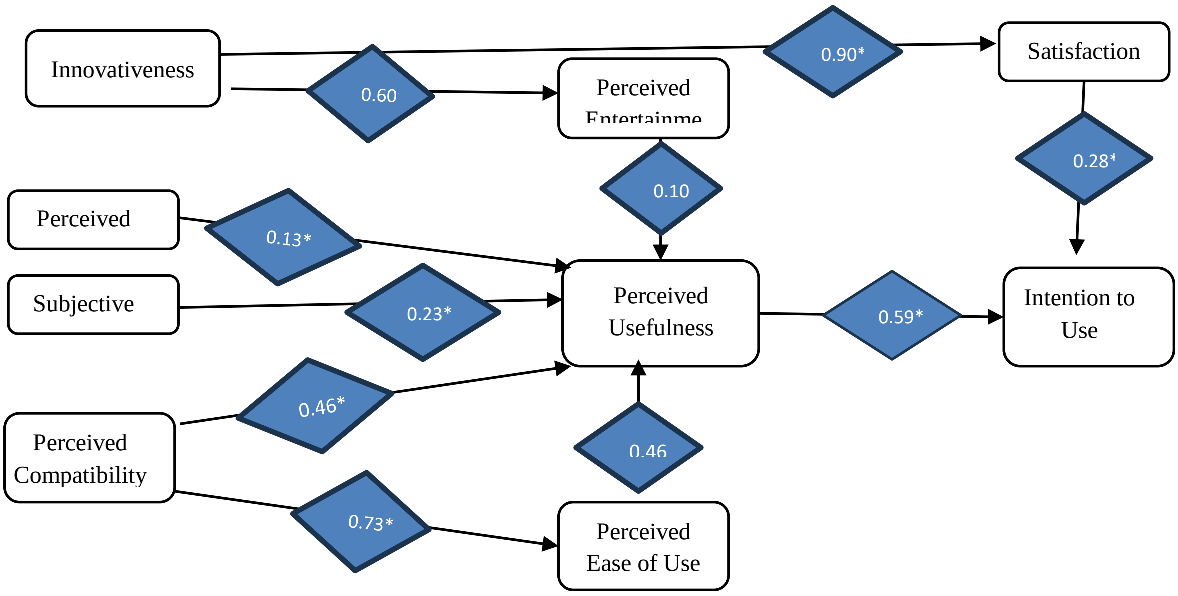
Summary of Hypothesis Tests

	Hypothesis	Standardized coefficient	SE	CR	P	Supported
1a	Innovativeness -> Perceived Entertainment	0.632	0.103	8.042	Yes	<0.001
1b	Innovativeness -> Satisfaction	0.999	0.125	9.645	Yes	<0.001
2a	Perceived Entertainment -> Perceived Usefulness	0.114	0.041	-2.72	Yes	0.007
2b	Perceived Entertainment -> Satisfaction	-0.13	0.057	-2.078	No	0.058
3a	Perceived Trust -> Perceived Usefulness	-0.125	0.055	-2.288	Yes	0.022
4a	Subjective norm -> Perceived Usefulness	0.234	0.059	4.197	Yes	<0.001
5a	Perceived Compatibility -> Intention to Use	0.187	0.109	1.699	No	0.089
5b	Perceived Compatibility -> Perceived Ease of Use	0.722	0.059	12.468	Yes	<0.001
5c	Perceived Compatibility -> Perceived Usefulness	0.47	0.082	6.199	Yes	<0.001
6a	Perceived Security -> Intention to Use	0.028	0.052	0.537	No	0.591
6b	Perceived Security -> Perceived Usefulness	-0.029	0.054	-0.596	No	0.551
7a	Satisfaction -> Intention to Use	0.168	0.081	2.035	Yes	0.042
8a	Perceived Usefulness -> Intention to Use	0.464	0.084	5.036	Yes	<0.001
9a	Perceived Ease of Use -> Intention to Use	0.05	0.056	8.899	No	<0.051
9b	Perceived Ease of Use -> Perceived Usefulness	0.467	0.056	8.899	Yes	<0.001

Figure 2 illustrates how the integrated model describes the combined impacts of satisfaction and perceived usefulness on intention to use. These effects are captured in the integrated model.

Figure 2

*Results of Hypothesis Tests: *p < 0.001*



DISCUSSION AND IMPLICATIONS

The study holds significant implications for various stakeholders, including local authorities, software developers, and researchers. By examining user attitudes towards SCMA, we can gain valuable insights into their success and impact. With the growing popularity of these applications in recent years, understanding user acceptance is essential for sustained development and enhancement. This study contributes to this objective by employing an enhanced framework based on SEM, which supports a user-centric approach to decision-making. The proposed integrated user acceptance model not only fits well with the acquired sample data, but also confirms the predicted causal pathways. As such, it serves as a useful tool for both practitioners and scholars alike in predicting and improving user acceptance of SCMA. This study provides both practical and theoretical insights into smart city technology, contributing significantly to the expanding literature in this field. Understanding user attitudes, as facilitated by our research methodology, is essential to the effective deployment and advancement of SCMA, which are becoming increasingly prevalent. Recent research highlights the importance of a user-centered decision-making process, supported by an advanced framework based on SEM. The user acceptance model developed in this study shows strong fit indices when applied to both the model and sample data, validating the postulated causal relationships.

Technological advances, particularly the integration of wireless sensor networks with computer networks, have revolutionized the Smart City paradigm, ushering in a new age of urban innovation. This study utilized Structural Equation Modeling (SEM), a sophisticated statistical technique, to investigate the complex theoretical model of user acceptability. SEM enables the analysis of intricate relationships between variables such as perceived usefulness, perceived ease of use, and user attitudes toward SCMA. This approach provided a thorough evaluation of the cause-and-effect relationships among these factors and confirmed the overall compatibility of the model with real-world data.

Meanwhile, TAM remains an extensively employed theoretical framework for understanding technology adoption. According to TAM, user perception of usefulness and ease of use are key determinants of their attitudes toward technology, which in turn influence users' intention to engage with technology. TAM was applied in this research project to investigate the factors that impact the adoption and use of SCMA by stakeholders. By evaluating the perceived usefulness and perceived ease of use of the application, the research provided valuable insights into users' perceptions of its benefits and usability. Through the integration of SEM and TAM, this research provided a comprehensive understanding of the factors influencing SCMA acceptance at the user level. The findings of this study provide valuable guidance to local authorities and software developers in designing more user-centric and effective SCMA that meet user requirements. Furthermore, this research makes a theoretical contribution to the discourse on user acceptance of technology by validating the integrated user acceptance model, which could be applicable in a wide range of contexts outside SCMA.

While it is impractical to cover every aspect of the Smart City concept, our architectural framework aims to highlight the most critical elements of the Smart City environment. Future research will explore several key areas, including real-time information identification, the development of a unified semantic knowledge model, the integration high-quality data using TAM to support decision-making, and the clarification of data interoperability and scalability within our architectural framework.

As indicated earlier, the overall model reveals that perceived usefulness and enjoyment significantly influence users' intention to adopt SCMA. Specifically, perceived usefulness is influenced by factors such as perceived enjoyment, happiness, trust, compatibility, and ease of use. These findings suggest that our proposed model, consistent with earlier studies on the adoption of new smart city mobile systems (Huang et al., 2007; Park & Kim, 2013), accurately links the essential social and psychological components of these services. The structural study theory was developed by determining significant correlations among the nine components indicated above. A SEM analysis was then carried out using bootstrapped data from thousands of smart city mobile application users in Türkiye.

One of the key discoveries was that innovativeness plays a pivotal role in user satisfaction and perceived enjoyment. Additionally, perceived trust, satisfaction, and compatibility, and ease of use were identified as major drivers of perceived usefulness, which in turn substantially influenced users' intent to adopt SCMA. These results align with previous research (Shin & Shin, 2011; Park & Kim, 2013; Park & del Pobil, 2013; Abdin et al., 2020) which revealed that attitudes toward mobile technology are influenced by perceived usefulness. Our findings further contribute to the existing body of knowledge by demonstrating that these qualities are equally important factors in the context of SCMA. From a pragmatic viewpoint, the SCMA industry can leverage this comprehensive approach to develop strategic initiatives that foster greater adoption and success of smart city mobile applications.

Even though many SCMA providers offer their services for free, their ultimate aim is to penetrate the mainstream smartphone market, optimize profits, and deliver value to users. To achieve these objectives, providers should prioritize shaping user attitudes and behaviors, recognizing the significant influence these factors have on user adoption. Empirical evidence shows that perceived usefulness and system quality are key determinants of user intentions to adopt SCMA. Therefore, the industry should focus on improving consumers' psychological perceptions of these factors to improve user engagement and satisfaction. Enhancing user satisfaction with SCMA is crucial for providers' success. Consequently, the industry must allocate more resources to develop resilient and reliable infrastructures that improve mobile experiences and elevate service quality.

CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH DIRECTIONS

To develop new universal platforms and systems for Web 3.0, the industry must address several long-term concerns. This includes users are concerned about system and service quality when deciding whether to use smart city mobile application services and municipalities need to improve the quality of their services to meet user expectations.

The outcomes of this research provide valuable insights into the implementation of SCMA. However, future research must address the various challenges that remain unaddressed. A key limitation of the current study is the lack of attention to the differences among participants. Venkatesh et al. (2003) highlighted in their UTAUT model, that individual characteristics such as gender, age, and race, as well as social factors such as performance expectancy, effort expectancy, voluntariness, and subjective norms, significantly influence user attitudes and intentions to adopt new technology. Since all respondents in this study were from Türkiye, it is likely that users from other countries would exhibit different adoption patterns based on their unique personal and national circumstances. Future research should explore how these individual attributes moderate the results, using a broader sample to improve the model's generalizability.

In addition, future studies should explore how emerging technologies impact user satisfaction and acceptance of SCMA. Technological innovations like artificial intelligence, augmented reality, and blockchain have the potential to revolutionize SCMA by introducing new features and enhancing user experiences. Understanding how these technologies impact user perceptions and behaviors will provide useful insights for developers and regulators. In addition, longitudinal studies could track changes in user attitudes and behaviors over time, offering a dynamic perspective on SCMA adoption and highlighting trends that can guide future development strategies.

This study contributes to the systematic understanding of SCMA. Future research can build on these findings by addressing the identified limitations, as significant challenges remain within this field that warrant further investigation. By adopting a user-centered approach in future studies, smart city applications can be designed and implemented to meet users' evolving needs and expectations, ultimately fostering greater acceptance and sustained use.

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