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Understanding the Drivers of Adoption for Blockchain-enabled Intelligent Transportation Systems

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Abstract: This study tended to present a model for examining the effective factors on adoption of blockchain-based intelligent transportation systems (ITS). The methodology employed was correlational descriptive approach using structural equation modeling. The research involved collecting data through a survey, which was completed by 368 individuals residing in prominent cities across Iran. The findings of the study suggest that perceived quality of digital services significantly impacts perceived ease of use, perceived usefulness, and trust in a positive manner. Additionally, the positive influence of information technology infrastructure and social influence on perceived ease of use and perceived usefulness is evident. Moreover, perceived ease of use and perceived usefulness play pivotal roles in building trust and fostering adoption of blockchain-based ITS. The study also highlights the positive and significant impact of transparent governance on trust and adoption. Furthermore, policies and regulations are identified as key drivers of perceived usefulness and adoption of such systems. Lastly, perceived trust and security are found to positively influence adoption. These findings underscore the potential of the examined variables to serve as robust predictors for the adoption of blockchain-based ITS by citizens.

Keywords: adoption of blockchain-based intelligent transportation system; perceived quality of digital services; policies and regulations; technology acceptance; trust; transparent governance

1 INTRODUCTION

Despite considerable progress in infrastructure development, the surge in vehicle numbers over the last twenty years has made the transportation strategies previously developed and put into action insufficient for tackling the growing issues of traffic congestion. There is an increasing importance placed on the integration of intelligent transportation systems (ITS). These systems play a key role in alleviating traffic issues, enhancing traffic flow, and fostering the development of smart road infrastructure. Users benefit from valuable updates on seat availability and real-time traffic conditions, leading to improved safety, enhanced comfort, and reduced travel times [1, 36]. ITS have evolved through the incorporation of integrated information and communication technologies within transportation networks. These systems facilitate the seamless integration of vehicles, road infrastructure, and individuals by leveraging advanced technologies like Radio Frequency Identification (RFID) scanners and Global Positioning System (GPS) for effective traffic data collection. Additionally, Advanced Traveller Information Systems (ATIS) aid travellers in making informed decisions, while advanced management systems oversee transportation operations. The integration of electric vehicles and intelligent traffic systems further contribute to the efficiency and effectiveness of modern transportation systems [2, 39]. By optimizing energy consumption efficiency in transportation systems, we can reduce overall carbon emissions and promote sustainability for future generations [48].

Fostering a trustworthy collaboration and developing a secure, reliable and decentralized architecture is crucial for maintaining a profitable, sustainable, efficient, and safe ecosystem of ITS. In response to this requirement, blockchain technology presents outstanding solutions. With the advent of Bitcoin, blockchain technology has revolutionized the landscape of digital currencies. This emerging decentralized technology embodies a distributed ledger that possesses the capability to uphold an indelible log of transactions executed within a network. While initial research predominantly concentrated on the implementation of blockchain within the financial domain, scientific communities have recently redirected their efforts towards exploring its application in the context of the Internet of Things (IoT) [3], leveraging it's decentralized, trustworthy, and secure environment. Recognizing its enormous potential, blockchain technology has garnered substantial attention from both industry and academia in recent times. As per a report by Deloitte in 2019, blockchain is projected to emerge as one of the top five strategic priorities over the upcoming two years [4]. Some of the advantages of blockchain technology may include anonymity, transparency, accountability, collaboration, financial efficiency, cooperation, agility, privacy, security, and scalability. These advantages of blockchain-based ITS have garnered significant attention from academics and experts, leading to development of several applications and prototypes in this field. Successful implementations of blockchain-based ITS encompass shared initiatives, systems for traffic control and management, as well as ad-hoc vehicle networks [2]. Considering the importance of blockchain technology in transportation systems, this study tends to present a model for examining the effective factors on adoption of blockchain-based ITS.

2 RESEARCH HYPOTHESES

2.1 Trust and Adoption of Blockchain-based ITS

Throughout the history of business, trust has served as a foundational concept for facilitating transactions and exchanges. It plays a crucial role in establishing and enhancing the quality of relationships through the process of making and fulfilling commitments [38]. Trust means customer tendency to have confidence in abilities and capabilities of a trademark in performing assigned tasks [5]. According to Morgan and Hunt [6], trust is characterized as the perception of confidence in exchanges, dependency, partner reliability, and they argue that trust forms the cornerstone of a dedicated relationship. Belief in the reliability and trustworthiness of the other party fosters a robust, genuine, equitable, and advantageous collaboration. In instances where unexpected product issues arise, the brand's trustworthiness becomes a dependable factor for customers, contributing to the growth, sales, and promotion of products or services [7, 8].

The configuration of trust holds significant importance in cultivating interest in relationship marketing. Several researchers have recognized trust as a vital element in establishing and nurturing fruitful customer relationships and fostering customer loyalty [9, 10]. In particular, trust is more important in the electronic environment due to complexity and diversity of electronic interactions, and thus insecurity and unpredictable behaviors [11, 12]. Various studies also indicate the role of trust in behavioral intentions and use of services. Therefore, it is assumed that:

H_1: Citizen trust is effective on adoption of blockchain-based ITS.

2.2 Perceived Security and Adoption of Blockchain-based ITS

Security, which involves protection and support of personal information of customers, transactions, and secure events to prevent misuse, is crucial for growth of any online business. Security includes secure and reliable exchanges and transactions, as well as robust systems and reliable support [13]. Information security refers to protection of information and minimized risk of information disclosure in unauthorized areas. Information security is a set of tools used to prevent theft, attacks, crimes, espionage, sabotage, and to study methods of data protection in computers and communication systems against unauthorized access and changes. By definitions, security refers to a set of measures, methods, and tools used to prevent unauthorized access and changes in computer and communication systems [14-16]. With rapid growth of e-commerce, government and private institutions perceive greater risk associated with protecting their information security. Developing electronic security as a field enables organizations to better understand a wider range of similarities between attacks occurring in their secure environment and take appropriate countermeasures. Protecting the privacy of confidential information has become a benchmark for success in the business world, as it enhances the reputation of organizations and gain the trust of individuals. Studies have also emphasized the role of perceived security in ITS [2]. Therefore, it is assumed that:

H_2: Perceived security is effective on adoption of blockchain-based ITS.

2.3 Transparent Governance and Adoption of Blockchain-based ITS

Transparent governance entails the practice of open communication and disclosure of information among citizens, organizations, or governments, while also taking into account privacy limitations [2]. Blockchain technology offers a reliable and transparent mechanism that ensures the permanence of all information. Transparent governance involves implementing a government system characterized by openness, clearly defined processes and procedures, and seamless access to public information for citizens. Enhanced transparency fosters ethical consciousness in public services by promoting information sharing, thereby ensuring accountability for the performance of individuals and organizations responsible for managing resources or holding governmental roles. Increasing transparency by providing users with the ability to track all system functions helps build trust in the organization and its programs [2]. Similarly, it positively influences the success of blockchain-based intelligent transportation initiatives. Hence, the success of blockchain-based ITS heavily relies on the implementation of transparent governance as a pivotal factor [2]. Thus, it is assumed that:

H_3: Transparent governance is effective on adoption of blockchain-based ITS.

H_4: Transparent governance is effective on citizen trust in adopting blockchain-based ITS.

2.4 Policies, Regulations and Adoption of Blockchain-based ITS

Policies and regulations refer to the guidelines and rules established by the government to oversee and regulate industries in their adoption of new technologies [2]. They are considered as a fundamental and influential factor in fostering innovation [17, 40]. Given that blockchain is a recently emerged technology, the introduction of new regulations presents challenges, including the definition of digital ownership and access rights, without established laws and regulations in place as of yet [18]. This can either promote or hinder the acceptance of technology, especially the success of blockchain-based ITS projects. Therefore, policies and regulations are defined as one of the key contributors to success in blockchain-based ITS projects [2]. Therefore, it is assumed that:

H_5: Policies and regulations are effective on adoption of blockchain-based ITS.

H_6: Policies and regulations are effective on the perceived usefulness of blockchain-based ITS.

2.5 The Perceived Usefulness and Ease of Use

The growth and increasing development of communication technology has led to a revolution in various aspects of human life and performance of businesses. Technology has led to changes in performance and attitude of people, companies, and governments, resulting in establishment of new industries, new jobs, and innovation in organizational processes [27, 40]. Various theoretical frameworks have been formulated and tested to assess the level of technology acceptance by users, the most important of which is Technology Acceptance Model (TAM) [12, 19, 43]. Davis [19] introduced the TAM to elucidate technology usage patterns and the factors associated with technology adoption. The TAM model is rooted in the Theory of Reasoned Action. It has been suggested that the TAM is the most reliable predictor of behavioral intention towards usage. The TAM rests on two core elements, namely "perceived usefulness" and "perceived ease of use." Perceived ease of use pertains to an individual's conviction that minimal physical and mental exertion is needed to operate a given technology [12, 19]. Perceived usefulness denotes an individual's conviction that the utilization of technology will enhance their job performance [19]. Studies show that perceived usefulness and ease of use are effective on attitude (positive or negative personal feelings resulting from evaluation of certain behavior) while using a technology, which lead to decision to use that technology and ultimately manifest in actual usage. Moreover, the research conducted suggests that trust plays a mediating role in the impact of perceived usefulness and perceived ease of use on behavioral intentions. Therefore, it is assumed that:

H_7: Perceived ease of use is effective on perceived usefulness.

H_8: Perceived ease of use is effective on citizen trust on adoption of blockchain-based ITS.

H_9: Perceived ease of use is effective is effective on adoption of blockchain-based ITS.

H_{10}: Perceived usefulness is effective on citizen trust on adoption of blockchain-based ITS.

H_{11}: Perceived usefulness is effective on adoption of blockchain-based ITS.

2.6 Social Influence

Social influence refers to how one perceives the importance of others' opinions in adopting new technologies. The intention of users to adopt a specific technology is influenced by social pressure from peers, family, and media [20, 41, 46]. According to Venkatesh et al. [21], social influence pertains to how much an individual perceives that others endorse their adoption of the new system. Prior research has demonstrated the effectiveness of social influence on users' perceived ease of use, perceived usefulness, and behavioral intentions. Therefore, it is assumed that:

H_{12}: social influence is effective on perceived usefulness.

H_{13}: social influence is effective on perceived ease of use.

2.7 Perceived Quality of Digital Services

According to most experts, the surest way to succeed is to remain in the minds of customers, and this can only be achieved through producing high-quality products and services. The quality of services has become a key marketing tool for achieving competitive differentiation and promoting customer loyalty. Awareness of the concept of service quality and striving to improve it has led to provision of high-quality services; customer satisfaction can be increased by improving the level of service quality [22, 37]. In various industries and sectors, companies tend to differentiate themselves and retain customers by providing better services. Zeithaml et al. [23] define electronic services as web-based services that are delivered to customers via the internet. Exceptional service quality is regarded as a pivotal element for achieving success in a competitive service market [44]. Numerous studies have highlighted that the perceived service quality has a direct impact on customer trust. Electronic service quality encompasses all interactive stages that consumers experience through websites, including the extent to which websites facilitate efficient and effective purchasing and delivery processes. In general terms, electronic service quality can be described as customer-oriented online services facilitated by consumers, integrated with technology and systems provided by service providers, with the aim of enhancing the relationship between customers and service providers [24, 25]. Past research indicates that the perceived quality of public transportation services has a notable positive influence on the perceived ease of use and utility. Therefore, it is assumed that:

H_{14}: Perceived digital service quality is effective on perceived usefulness.

H_{15}: Perceived digital service quality is effective on perceived ease of use.

H_{16}: Perceived digital service quality is effective on citizen trust on adoption of blockchain-based ITS.

2.8 Information Technology Infrastructure

Information technology, as a new infrastructure, has attracted much attention to its impact on organizations. This infrastructure, generally defined as collective utilization of electronic devices, remote communication, software, decentralized computer stations, and integrated media, has had a profound effect on organizing spatial distances and consequently on other systems. Information technology infrastructure represents physical capital (i.e., computers, network equipment, and databases) that provides information sharing and accessibility for the company [26]. Currently, information technology is an incentive for globalization of productions and markets, increasing the dynamism and flexibility of services and financial flows, often setting the stage for increased performance and efficiency. Comprehensive information and information technology used at the right time can increase creativity and technology while preventing the waste of resources, unnecessary and unintended rework, and above all, fruitless decision-making. Therefore, it is assumed that:

H_{17}: Information technology infrastructure is effective on perceived usefulness.

H_{18}: Information technology infrastructure is effective on perceived ease of use.

Overall, as noted, the role of the variables mentioned in this study in ITS has been emphasized throughout the theoretical literature. However, review of empirical literature shows that few studies have provided a model to examine the effective factors on adoption of blockchain-based ITS. Therefore, the main problem of this study is to present a model to examine the effective factors on adoption of blockchain-based ITS. Drawing upon the theoretical literature and a conceptual framework derived from previous studies, Figure 1 illustrates the conceptual model for this research. In this model, perceived digital service quality, information technology infrastructure, social influence, transparent governance, policies and regulations, and perceived security are considered as independent variables, perceived ease of use, perceived usefulness, and trust as mediating variables, and adoption of blockchain-based ITS as dependent variable.

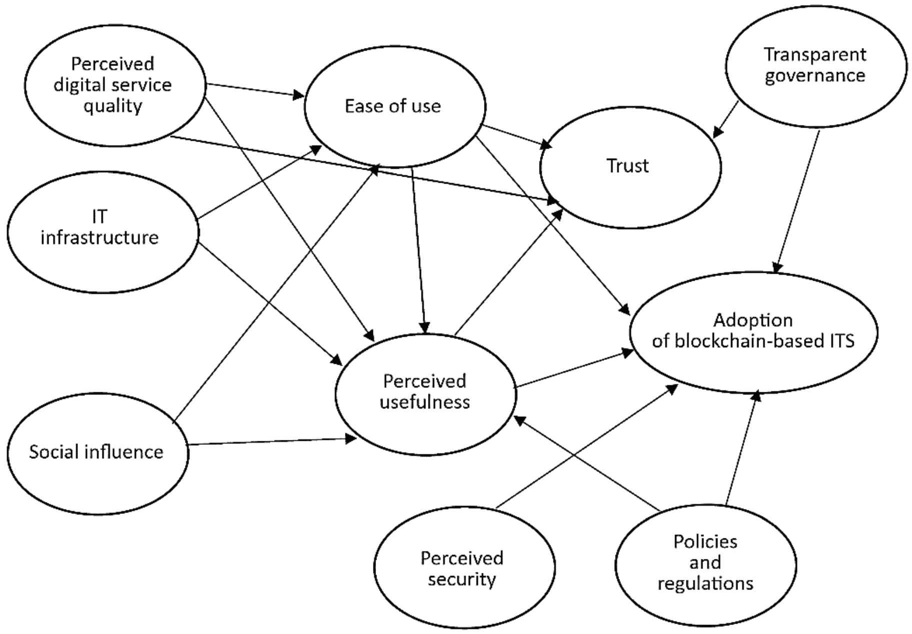

Figure 1 Conceptual model

3 RESEARCH METHODOLOGY

This section will detail the research methodology employed in our study.

3.1 Population and Sample

The participants of this study were residents of major cities in Iran. For this purpose, 450 questionnaires were distributed among citizens of these metropolises, out of which 392 questionnaires were returned, and 24 questionnaires were excluded from analysis process due to incomplete responses, ultimately leaving 368 questionnaires for analysis. Additionally, 61% of the study's participants were male, while 29% were female. Among the participants, 39% were aged between 20 and 30 years, 36% were between 31 and 40 years old, 19% were between 41 and 50 years old, and 6% were over 50 years of age.

3.2 Data Collection Instruments

To measure the variables, a questionnaire was used. The questionnaire consisted of 56 items. The perceived usefulness was measured using Chen and Chao's [28] questionnaire, which consists of 5 items. The ease of use was measured using Chen and Chao's [28] questionnaire, which consists of 5 items. Social influence was measured using Venkatesh et al.'s [21] questionnaire, which consists of 4 items. Transparent governance was measured using Ofochebe's [29] questionnaire, consisting of 5 items. Policies and regulations were measured using Zhu et al.'s [17] questionnaire, which consists of 3 items. Trust was measured using Shankar et al.'s [30] questionnaire, which consists of 6 items. Perceived security was measured using Gao et al.'s [20] questionnaire, which consists of 5 items. The quality of digital services was measured using a 15-item questionnaire, assessing tangibility [31] with 5 items, convenience [31] with 6 items, and customer satisfaction [9, 32, 33] with 4 items. Infrastructure technology was measured using Ravichandran et al.'s [34] questionnaire, which consists of 5 items. Adoption of blockchain-based ITS was measured using Chen et al.'s [35] questionnaire, which consists of 3 items.

4 RESULTS

4.1 Validity and Reliability of Instruments

The evaluation of the measurement model involves examining the reliability (internal consistency) and validity (discriminant validity) of constructs and instruments. Three criteria for evaluating construct reliability are applied: 1) the reliability of individual items, 2) the composite reliability of each construct, and 3) the average variance extracted (AVE). For the reliability of individual items, a factor loading of 0.6 or higher in confirmatory factor analysis indicates the adequacy of each item within that construct. Additionally, the factor loadings of items should be statistically significant at the 0.01 level [12]. The significance of factor loadings was determined by calculating the T-value through bootstrap testing with 500 subsamples. The composite reliability of each construct was evaluated using Dillon-Goldstein's rho method (ρ_c). Acceptable ρ_c values should be 0.7 or higher. The third measure for evaluating reliability AVE. They suggest AVE values of 0.50 or greater, signifying that the construct accounts for approximately 50 percent or more of the variance in its indicators [27]. Tab. 1 displays the factor loadings, composite reliability, and AVE of the variables. The values presented in these tables demonstrate sufficient and satisfactory reliability of the constructs.

Table 1 The results of measurement model

Variable		Item	Factor loading	Cronbach's alpha	CR	AVE
Perceived digital service quality	Tangibility	1	0.853	0.874	0.909	0.668
		2	0.883			
		3	0.830			
		4	0.743			
		5	0.769			
	Convenience	1	0.779	0.806	0.861	0.509
		2	0.722			
		3	0.725			
		4	0.706			
		5	0.666			
		6	0.676			
	Customer satisfaction	1	0.80	0.795	0.867	0.619
		2	0.814			
		3	0.747			
		4	0.785			
IT infrastructure		1	0.721	0.864	0.901	0.647
		2	0.764			
		3	0.826			
		4	0.812			
		5	0.888			
Social influence		1	0.828	0.782	0.858	0.603
		2	0.844			
		3	0.747			
		4	0.676			
Perceived usefulness		1	0.669	0.855	0.840	0.514
		2	0.799			
		3	0.704			
		4	0.651			
		5	0.751			
Perceived ease of use		1	0.861	0.855	0.895	0.631
		2	0.739			
		3	0.718			
		4	0.848			
		5	0.796			
Trust		1	0.818	0.920	0.938	0.715
		2	0.850			
		3	0.874			
		4	0.855			
		5	0.869			
		6	0.804			
Transparent governance		1	0.827	0.864	0.900	0.645
		2	0.861			
		3	0.848			
		4	0.713			
		5	0.761			
Policies and regulations		1	0.737	0.756	0.807	0.583
		2	0.721			
		3	0.828			
Perceived security		1	0.827	0.895	0.923	0.706
		2	0.875			
		3	0.822			
		4	0.756			
		5	0.912			
Adoption of blockchain-based ITS		1	0.862	0.842	0.905	0.760
		2	0.899			
		3	0.854			

In evaluating construct validity or discriminant validity, Nazari-Shirkouhi et al. [12] proposes two criteria: 1) Items within a construct should exhibit the highest factor loading on their own construct, indicating minimal cross-loading on other constructs. Alipour et al. [27] recommended that the factor loading of each item on its designated construct should be at least 0.1 higher than its loading on any alternative construct. The second criterion states that the square root of the AVE for a construct should exceed its correlation with other constructs. This signifies that the construct's correlation with its own indicators is stronger than its correlation with other constructs [42].

As per the data in Tab. 2, the square root of AVE exceeds the correlations with other variables for all variables. This confirms that the variables meet the second criterion for discriminant validity. Furthermore, the values below the diagonal in the correlation matrix are analyzed to investigate the interrelationships among variables.

4.2 Structural Model Testing

To forecast the adoption of blockchain-based ITS, the conceptual model under scrutiny was analyzed through Structural Equation Modeling (SEM). The Partial Least Squares (PLS) approach was applied to estimate the model in line with the hypotheses. Furthermore, the bootstrap technique (utilizing 700 subsamples) was utilized to compute *t*-values for assessing the significance of path coefficients [42]. Fig. 2 depicts the tested model, illustrating the connections among the variables. The figures within the circles indicate the variance explained by the variables.

Tab. 3 reports the estimated path coefficients and the explained variances of the variables.

As indicated in Tab. 3, the perceived quality of digital services exerts a significant and positive influence on perceived ease of use, perceived usefulness, and trust. Furthermore, the impact of information technology infrastructure and social influence is both significant and positive on perceived ease of use and perceived usefulness. Perceived ease of use and perceived usefulness demonstrate a positive and significant effect on trust and the adoption of intelligent blockchain-based transportation systems. Transparent governance exhibits a positive and significant effect on trust and the adoption of intelligent blockchain-based transportation systems. Moreover, policies and regulations have a positive and significant effect on perceived usefulness and the adoption of blockchain-based ITS. Additionally, perceived trust and security yield a positive and significant impact on the adoption of blockchain-based ITS. Furthermore, the model explains 67% of the variance in the adoption of blockchain-based ITS, 56% of the variance in trust, 28% of the variance in perceived ease of use, and 56% of the variance in perceived usefulness. The indirect coefficients are presented in Tab. 4.

Tab. 4 reveals that the perceived ease of use plays a significant and positive mediating role in the impact of perceived digital service quality, social influence, and IT infrastructure on the adoption of blockchain-based ITS. The perceived usefulness also has a positive and significant mediating role in the effect of the perceived digital service quality, social influence, policies and regulations, and IT infrastructure on adoption of blockchain-based ITS. In the adoption of blockchain-based ITS, trust acts as a positive and significant mediator in the impact of perceived digital service quality, perceived ease of use, perceived usefulness, and transparent governance.

In this study, the absolute GOF index for the tested model was computed as 0.597, indicating a satisfactory fit of the model. Values exceeding 0.36 signify acceptable and adequate model quality.

Table 2 Matrix of correlation and square root of AVE of variables

	ITS	Digital Service Quality	Perceived Ease of Use	Perceived Security	Perceived Usefulness	Policy & Regulations	Social Influence	Technology infrastructure	Transparent Governance	Trust
Blockchain-based ITS	**0.872**									
Digital Service Quality	0.528	**0.815**								
Perceived Ease of Use	0.448	0.509	**0.794**							
Perceived Security	0.481	0.618	0.376	**0.840**						
Perceived Usefulness	0.545	0.676	0.485	0.596	**0.712**					
Policy & Regulations	0.596	0.624	0.482	0.569	0.587	**0.763**				
Social Influence	0.516	0.596	0.409	0.537	0.427	0.577	**0.776**			
Technology infrastructure	0.386	0.524	0.234	0.573	0.528	0.477	0.526	**0.804**		
Transparent Governance	0.476	0.396	0.162	0.397	0.502	0.389	0.354	0.428	**0.803**	
Trust	0.567	0.558	0.428	0.610	0.571	0.591	0.482	0.483	0.502	**0.846**

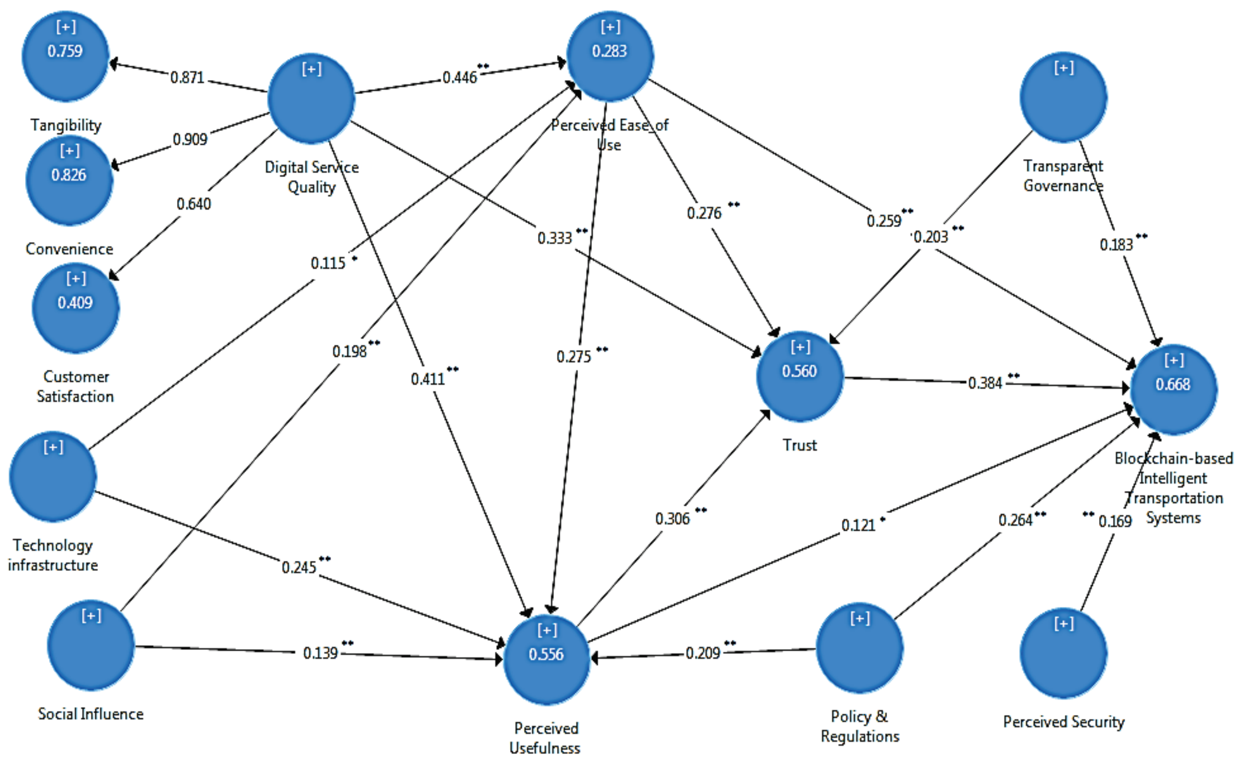

Figure 2 The tested model

5 DISCUSSION

This study tended to propose a model for examining the effective factors on adoption of blockchain-based ITS using the SEM method. The findings demonstrated that the proposed model exhibited a favorable fit with the collected data and successfully accounted for 67% of the variance in the adoption of blockchain-based ITS, 56% of the variance in perceived trust, 28% of the variance in perceived ease of use, and 56% of the variance in perceived usefulness.

The findings suggested that the perceived quality of digital services positively and significantly influences perceived ease of use, perceived usefulness, and trust, thereby enhancing the ease of use, perceived usefulness, and trust in blockchain-based ITS. In explaining this finding, if good services are provided and customer perceptions and beliefs about service quality are positively influenced, the level of trust in these services will significantly increase. In general, it can be concluded that service quality increases customer trust. Providing services as promised in a suitable, accurate, and reliable manner boosts customer trust.

Additionally, providing better digital services makes citizens perceive technology as easy to use and beneficial. Hence, it can be inferred that the quality of electronic services is closely associated with perceived usefulness, perceived ease of use, and customer trust, thereby aiding citizens in their decision-making process and promoting the adoption of blockchain-based ITS.

Table 3 Path coefficients and explained variance

Variable	β	t-value	p-value	Explained variance
On adoption of blockchain-based smart transportation system via:				
Transparent governance	0.183**	3.014	0.01	0.668
Policies and regulations	0.264**	5.811	0.01	
Perceived security	0.169**	2.874	0.01	
Trust	0.384**	7.296	0.01	
Perceived usefulness	0.121*	2.508	0.05	
Perceived ease of use	0.259**	5.327	0.01	
On trust via:				
Transparent governance	0.203**	4.216	0.01	0.56
Perceived usefulness	0.306*	5.388	0.01	
Perceived ease of use	0.276**	5.926	0.01	
Perceived digital service quality	0.333**	5.776	0.01	
On perceived usefulness via:				
Perceived ease of use	0.275**	5.411	0.01	0.556
Perceived digital service quality	0.411**	7.065	0.01	
IT infrastructure	0.245**	5.722	0.01	
Social influence	0.139**	2.922	0.01	
On perceived ease of use via:				
Perceived digital service quality	**0.446****	**7.080**	**0.01**	**0.283**
IT infrastructure	**0.115***	**2.409**	**0.01**	
Social influence	**0.198****	**3.713**	**0.01**	

*$p < 0.05$; **$p < 0.01$

Table 4 Indirect coefficients

Indirect paths	Indirect effects	t-value	p-values
Digital Service Quality→Perceived Ease of Use→Blockchain-based ITS	0.115	4.256	0.000
Social Influence→Perceived Ease of Use→Blockchain-based ITS	0.051	3.046	0.000
Technology infrastructure→Perceived Ease of Use→Blockchain-based ITS	0.03	2.195	0.05
Digital Service Quality→Perceived Usefulness→Blockchain-based ITS	0.050	2.605	0.009
Perceived Ease of Use→Perceived Usefulness→Blockchain-based ITS	0.033	2.275	0.05
Policy & Regulations→Perceived Usefulness→Blockchain-based ITS	0.025	2.313	0.021
Social Influence→Perceived Usefulness→Blockchain-based ITS	0.017	2.189	0.029
Technology infrastructure→Perceived Usefulness→Blockchain-based ITS	0.030	2.600	0.010
Digital Service Quality→Trust→Blockchain-based ITS	0.128	4.531	0.000
Perceived Ease of Use→Trust→Blockchain-based ITS	0.106	4.599	0.000
Perceived Usefulness→Trust→Blockchain-based ITS	0.118	4.225	0.000
Transparent Governance→Trust→Blockchain-based ITS	0.078	3.664	0.000
Digital Service Quality→Perceived Usefulness→Trust	0.126	4.954	0.000
Perceived Ease of Use→Perceived Usefulness→Trust	0.084	3.818	0.001
Policy & Regulations→Perceived Usefulness→Trust	0.064	2.699	0.007
Social Influence→Perceived Usefulness→Trust	0.043	2.503	0.013
Technology infrastructure→Perceived Usefulness→Trust	0.075	3.925	0.000

The findings further revealed a positive and significant impact of information technology infrastructure on perceived ease of use and perceived usefulness, ultimately resulting in heightened perceptions of ease of use and usefulness regarding blockchain-based ITS. In explaining this finding, if a company has the necessary technological infrastructure to electronically connect units and has the technology infrastructure for intelligent transportation activities, and if capacity of ITS infrastructure meets current needs, it will lead to increased perceived ease of use and perceived usefulness of blockchain-based ITS and, consequently, an increase in their adoption.

The findings indicated that social influence has a notably positive impact on perceived ease of use and perceived usefulness, contributing to an enhancement in the perceived ease of use and perceived usefulness of blockchain-based ITS. In explaining this finding, if trustworthy friends or family members recommend blockchain-based ITS, if a trusted agency (such as the police or a transportation authority) recommends it, and if a reputable source recommends and supports it, it leads to an increase in the perceived ease of use and perceived usefulness of blockchain-based ITS, thereby increasing the likelihood of their adoption.

Another finding of the study was that perceived usefulness and perceived ease of use have a significantly positive effect on trust and intention to use blockchain-based intelligent transportation systems, leading to an increased use of such systems. This result aligns with the Technology Acceptance Model (TAM), which underscores the significance of perceived usefulness and perceived ease of use in determining actual user behavior. In explaining this finding, if users perceive the adoption of blockchain-based ITS as easy, perceive it as easy to fulfill their needs, find it easy to learn to use the system, feel that it enhances their effectiveness in daily activities, and believe that the system contributes positively to their performance, their intention to use the blockchain-based ITS will increase. As per the TAM, perceived ease of use and perceived usefulness stand out as key factors influencing technology acceptance, and if technology improves individual efficiency and performance, it fosters a positive attitude toward that technology, leading to a greater willingness to use it.

Another finding was that transparent governance and adoption of blockchain-based ITS have a positive and significant effect, leading to increased adoption of ITS based on blockchain technology. This finding is consistent with Çaldağ and Gökalp [2], who identified transparent governance as one of the determinants of adopting blockchain-based ITS. When elucidating this discovery, it is important for open communication and information disclosure to exist between citizens and organizations or governments in relation to blockchain-based ITS. The government should ensure that citizens have easy access to public information related to ITS through transparent processes and procedures. Additionally, a high level of transparency and ethical awareness in public services should be promoted through information sharing. These efforts will lead to enhanced trust and, consequently, greater adoption of blockchain-based ITS.

Another finding is that perceived usefulness and policies and regulations have a positive and significant effect on the perceived usefulness and adoption of blockchain-based ITS. This finding is consistent with Çaldağ and Gökalp [2], who emphasized the importance of policies and regulations as one of the success factors of blockchain-based ITS. In explaining this finding, policies and regulations related to how to use ITS and policies and regulations to address issues that may arise during the usage of these systems lead to increased adoption of blockchain-based ITS.

Another finding is that perceived security has a positive and significant effect on adoption blockchain-based ITS. This finding is consistent with Çaldağ and Gökalp [2]. In explaining this finding, if users are not concerned about their personal information while using the ITS, not worried about their personal information being shared without their consent, not concerned about their shared information being misused by the company, and feel secure when using the services of the company, it will lead to increased adoption of blockchain-based ITS.

Another finding was that trust has a positive and significant effect on adoption blockchain-based ITS, leading to increased use of these systems. In explaining this finding, if performance of the system meets user expectations and they feel that the company is true to its promises, their willingness to use the blockchain-based ITS will increase. The trustworthiness of a brand serves as a dependable factor for customer retention, guaranteeing the development, sale, and advertisement of a product or service. Once trust is established, it creates the potential for mutually beneficial relationships between customers and companies. Therefore, it can be inferred that trust plays a vital role in customer satisfaction when utilizing blockchain-based ITS.

6 MANAGERIAL IMPLICATIONS

Given the role of perceived digital service quality in adopting blockchain-based ITS, it is suggested that officials of ITS provide accurate information on how services are delivered to citizens, offer timely information to citizens, provide reliable services, offer professional services to citizens, and ensure that employees are responsive to citizen requests and address issues and problems that arise.

Considering the role of technology infrastructure in adopting blockchain-based ITS, it is suggested that companies responsible for technology infrastructure have the necessary electronic infrastructure to connect different units, have technology infrastructure for ITS, and that the capacity of technology infrastructure meets the current needs of citizens.

Given the role of trust in utilizing blockchain-based ITS, it is suggested that the company fulfill its commitments to citizens, provide reliable services, meet customer expectations with proposed services, and consider the interests of citizens. Numerous researchers have emphasized the importance of trust in establishing and nurturing successful customer relationships and loyalty. They argue that customers require a sense of security in their engagements with service providers and must feel assured that these interactions are dependable enough to engender trust. The reliability of a brand serves as a guarantee for customers, enabling the development, sale, and promotion of products or services. When trust is established, it opens up the potential for mutually advantageous relationships between customers and companies.

Considering the role of transparent governance and policies and regulations in adopting blockchain-based ITS, it is recommended that clear and explicit policies and regulations be developed in the field of blockchain-based ITS, and that open communications and transparent information exist between citizens and organizations or companies responsible for ITS. Transparency helps increase trust in organizations and programs.

Considering the role of perceived security in adopting blockchain-based ITS, it is suggested that citizens should not be concerned about their personal information during their exchanges and transactions when using ITS. They should not worry that their personal information will be shared without consent, that the information they provide on websites will be misused, that their personal information will be shared with the bank website, and that a sense of security for citizens should be ensured in using ITS.

7 CONCLUSION

In summary, the findings indicate that the model variables examined serve as robust predictors of the adoption of blockchain-based ITS. Additionally, perceived ease of use, perceived service quality, social influence, and technological infrastructure play a significant positive mediating role in the adoption of blockchain-based ITS. Perceived usefulness also plays a significant positive mediating role in the impact of perceived digital service quality, social influence, policies and regulations, and technological infrastructure on the adoption of blockchain-based ITS. Trust similarly plays a significant positive mediating role in the impact of perceived service quality, perceived ease of use, perceived usefulness, and transparent governance on the adoption of blockchain-based ITS. Therefore, it is essential to take into account these model variables to enhance the adoption of blockchain-based ITS.

7.1 Limitations

This research involved a sample of citizens exclusively from key cities in Iran, hence limiting the generalizability of the results. Moreover, the findings rely on self-reported data. To enhance future investigations on the factors influencing the adoption of blockchain-based ITS, it is recommended that researchers employ qualitative analysis [41, 49], mixed methods, machine learning [44, 45] approaches, Fusion Models [47], artificial intelligence [50]. Furthermore, this study is correlational in nature, precluding the ability to draw causal conclusions about the relationships among the model variables.

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