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The Diffusion Model of NFC Technology in the Mobile Payment System in Iran

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ABSTRACT

This study aims to create a diffusion model for the diffusion of Near-Field Communication (NFC) technology in the mobile payment system in Iran. NFC technology is one of the technological applications that is spreading worldwide daily and being used in various industries. In recent years, the country's banking system has tried implementing it in electronic payments based on cell phones, but it has not yielded results. The study's statistical population is everyone over 18 who can use the banking system. It is an applied and mixed study (quantitative and qualitative) using a system dynamics approach. The results are summarized in four scenarios, with the fourth scenario providing the best results. By implementing this scenario, accompanied by an increase in contact rate, education and culture, and legal infrastructure, the growth of NFC technology among users of mobile phone-based payment systems in the country can be increased to an acceptable level.

Keywords

Technology diffusion, Near field communication technology, Mobile payment systems, System dynamics.

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1. Introduction

One of the technologies offered in mobile phones is Near-Field Communication (NFC). This technology has emerged in recent years and is growing and expanding. NFC technology is a communication standard for electronic equipment that can exchange data between two devices at a distance of less than 10 cm, with a bit rate of 106, 212, and 424 kbps and central frequency of 13.56 Mhz. The mobile payment system based on NFC is growing in many countries and can be used as an alternative to bank payment cards (Samouti and Fathy, 2020). This technology makes paying for goods or services possible by entering banking information into the installed software and bringing the mobile phone close to the card reader device equipped with an NFC chipset.

According to the statistics provided by the central bank and the "Shaparak" system, the growth of the use of the NFC system in Iran is very low, and the efforts made by the banks and electronic payment services providers have not resulted. In March 2015, the "Shaparak" published an instruction manual for the application of this system with the title "Introducing a payment model based on NFC technology in the country's payment network", but due to the lack of proper information, user training, and concerns of users about security and privacy, there is a long way to spread this technology in the country.

In this study, an effort will be made to pave the way for the diffusion of this technology by finding the effective indicators of the "NFC" technology, ranking them, and highlighting their most important.

The main question of this research is how to build the Near Field Communication technology diffusion model and the model validation method. This research can help improve electronic technologies in the payment system and grow the country's banking system.

2. Theoretical background and experimental background

2.1. Theoretical background

NFC technology is considered a communication standard for electronic equipment that can exchange data between two devices equipped with this technology at a distance of less than 10 cm. This feature can cause significant business growth in the consumer, producer, and seller sectors (Bojan et al., 2018). A significant advantage of NFC technology is that it prevents eavesdropping due to using short-range methods in interactions and transactions (Rahul et al., 2015).

Users of this technology can pay for goods or services by entering bank details into the mobile phone's software and bringing it close to the NFC-enabled device. The number of people choosing mobile payments based on NFC technology has also seen a huge jump in recent years. In 2017, 824 million people in the world used this payment method, and the number of users using this technology in mobile payment has increased to 1.3 billion people by 2020, which has grown by 13.5% compared to 2019 (NFC Forum, 2021).

In 2016, five banks, including Parsian Bank, Shahr Bank, Refah Bank, Mellat Bank, and Saderat Bank, unveiled NFC technology, which remained silent due to the lack of card readers equipped with this technology and the lack of widespread use of smartphones. In March 2020, despite the widespread use of smartphones equipped with NFC technology, the provision of POS devices equipped with this technology, and the issuance of a license for use by the Central Bank, it has yet to be well received. Non-establishment standards and unavailability of equipment, incompleteness of the necessary infrastructure, the reluctance of people to use NFC due to issues such as security, privacy and also the lack of necessary knowledge and awareness in this field caused the failure of the efforts made in Iran have been made to use this technology widely. By conducting this research, an effort will be made to remove barriers and provide a diffusion model based on the country's native culture.

2.1.1. Technology diffusion model

When the World Health Organization launched a global campaign to eradicate smallpox, it engaged in diffusion. When Apple launched the iPod, it released a new product (Dearing and Meyer, 2006). The diffusion process of new technologies has been studied for more than 30 years, and one of the most popular diffusion models is described by Rogers in the book Diffusion of Innovations (Sherry and Gibson, 2002). According to Rogers, "technology is an action plan, a tool that reduces uncertainty in causal loop relationships involved in achieving a desired result" and consists of two parts: hardware and software (Sahin, 2006).

Hardware is "a tool that embodies technology in the form of a material or physical object", and software is a "tool database" (Rogers, 2003). Since software (as a technological innovation) has a low level of observability, its adoption rate is very slow. According to Rogers (2003), acceptance is a decision about "full use of an innovation as the best available course of action" and rejection is a decision "not to adopt an innovation".

Rogers (2003) defined diffusion as a process in which technology is transferred through certain channels over time among the members of a social system.

2.1.2. Mobile phone payment systems

It refers to systems in which the process of paying for a product or service and financial transactions between the seller and the buyer can be done using a mobile phone and related software. "Mobile phone payment system" technology provides banking and financial facilities for all kinds of services and products through mobile phones (Sharma and Mathuria, 2018). Today, smartphones are used in various payments, such as online ticket purchases, online electronic transactions, transportation fares, bill payments and invoices for goods and services, and other similar cases. On the other hand, physical product purchases are possible through a "mobile payment system". Today, most electronic payment systems and payment tools can be used on mobile devices (Ometov et al., 2018).

"Mobile Payment System" is more than just a payment method. This system implements the processes of initiating, processing, and confirming financial transactions. Although different versions of mobile phone-based payment may have similar functions, their design and implementation are different due to methods and structures (Ahmed et al., 2021).

2.1.3. Near field communication technology

It is one of the latest short-range wireless communication technologies that provide secure communication between electronic devices and similar devices with this technology from a distance of approximately 10 cm (Rahul et al., 2015). NFC technology is an international interface and protocol standard for simple wireless communication between near-connected devices developed by "International Organization for Standardization". NFC devices communicate at bit rates of 106, 212, and 424 kbps. This International Standard defines communication modes for an NFC interface and protocol using inductively coupled devices operating at 13.56 MHz for connecting computer peripherals (Mohandas et al., 2015). In the electronic payment system by NFC, both the mobile phone and the card reader must be equipped with this technology.

2.1.4. System dynamics

System dynamics models are mathematical causal loop models whose basic assumption is simulation (Safaie et al., 2022). Results can predict a system's behavior accurately if its structure is presented accurately (Bastan et al., 2018). In system dynamics, Vensim software is used for simulation. System dynamics were presented in the mid-1950s by one of the professors of the Massachusetts Institute of Technology named Forrester as a new method for managing the

performance of companies. Experts believe that the human brain cannot correctly interpret the behavior of social systems using linear and one-way logic. Hence, multi-loop nonlinear feedback systems should be used to analyze various phenomena. By simulating the system's dynamics, the expertise was able to identify the root of the organizational problems of General Electric Company. By proving the effectiveness of system dynamics and technological progress, the use of computer software to implement this method was expanded (Vennix et al., 1997). In the early introduction of system dynamics, this approach was only used to solve organizational management problems. In 1970, the experts faced the challenge of using the system dynamics to analyse the problem of lack of resources caused by the growth of the human population. They created the first draft of the world's dynamic socio-economic system model and introduced it as a global dynamic model.

The system dynamics approach is based on concepts such as feedback loop and stock flow, and the authors will introduce these concepts and related definitions.

2.1.5. Causal loop diagram

Systems are interconnected nests in feedback loops whose connections cause the system's behavior. The feedback loop is a process in which system outputs are used as system inputs during a cycle (Angerhofer and Angelides, 2000). Feedback loops have two types, positive and negative, as shown in Figure 1.

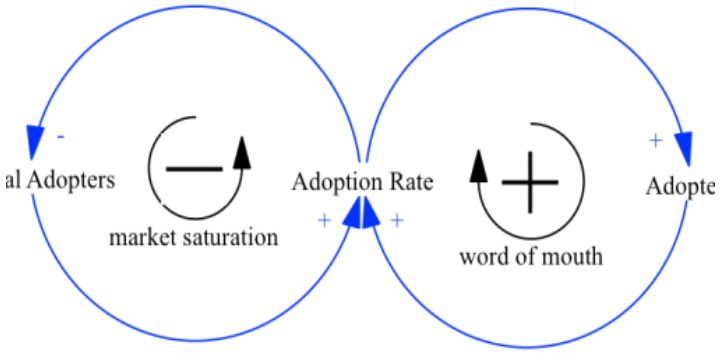

Figure 1. Positive and negative feedback loops (Angerhofer and Angelides, 2000)

2.1.6. Stock and flow diagram

The causal loop diagram visually displays the system's structure and qualitative analysis of the system. The stock and flow diagram (Figure 2) is a diagram that enables quantitative study and analysis of the system (Safaie et al., 2023). In system dynamics, anything whose value increases or decreases over time is called stock. Flow is the stock change rate (Sterman, 2000). Stock and flow models are usually simulated and analysed by computer software.

Figure 2. Stock - flow diagram in system dynamics (Sterman, 2000)

2.2. Experimental background

In this part of the research, studies on the diffusion of mobile payment systems using NFC technology have been investigated. The study conducted from 2007 to 2023 regarding mobile payment systems and NFC technology is given in Table 1. Various models have been used in this paper, such as fuzzy logic, the technology acceptance model, the integrated model of technology acceptance and use, the innovation diffusion model, and many others.

Most of the research has been done using various technology acceptance models, and only a few of these researches have used the technology diffusion model along with system dynamics. In cases where the system dynamics approach has been used, the issues of technology diffusion in electronic and mobile payment systems have been evaluated. The research done inside the country is in the field of similar technologies, and no research has been found on NFC technology in mobile payment.

According to the review of research (Table 1), severe weakness in this field has been observed, and the conducted investigations show the reluctance of the owners and internal researchers to use and diffusion of NFC technology in the mobile payment system. It is the first research conducted in the country in the field of spreading this technology in the mobile phone payment system based on NFC technology and with the approach of the country's system dynamics.

Table 1. Summary of studies

The author/authors	The research method	The variables
Chen and Chen (2007)	Bass diffusion model, system dynamics	Advertising and product price
Baran (2010)	Bass diffusion model and system dynamics	Word-of-mouth advertising, Advertising
Heydarieh and Shahabi (2012)	Technology acceptance and system dynamics	Perceived usefulness, perceived ease of use, user awareness, habit
Sarlak and Raustaei, Moghadasian (2013)	Technology acceptance model	Mental norms, ease of use, usefulness, attitude and security
Mousavi and Tajik (2013)	Bass diffusion, system dynamics	Word-of-mouth advertising, quality
Liébana-Cabanillas et al. (2013)	Technology acceptance model	Mental norms, ease of use, usefulness, attitude
Oh et al. (2014)	Technology acceptance model, innovation diffusion model	Service of usefulness, Ease of use, observability, testability, universality and expressed value, word-of-mouth advertising
Shin et al. (2014)	Technology acceptance model and technology	Perceived usefulness, perceived ease of use, innovation, optimism, responsibility, Intelligence,

The author/authors	The research method	The variables
	readiness model	Discomfort and insecurity
Longyara and Van (2015)	Technology diffusion model	Compatibility, Relative Advantage and perceived benefits, Complexity
Karsikko (2015)	Innovation diffusion model and technology acceptance model	Related benefits, Compatibility, Ease of use, Income, Influence of external networks, Use of payment cards, Cost, Security risks, Age, Income.
Oliveira et al. (2016)	An integrated model of technology adoption and use, Technology diffusion model of	Compatibility, Perceived technology security, Performance expectations, Innovation and social influence
Bastan et al. (2017)	Technology acceptance and system dynamics	Trust, Perceived usefulness, Ease of use, Satisfaction
Homayounfar and Nahavandi, Golbazzadeh (2017)	The spread of bass, System dynamics	Word-of-mouth advertising, The increase in advertising and research and development budgets.
Stanivuković et al. (2018)	Diffusion theory of innovation and fuzzy logic technology, Cost of migration, Innovation	Risk, Reliability, Compatibility, Multi-functionality, Applicability in the market, Limitations of existing technology, Cost of migration, Innovation.
Wang and Lai (2020)	Diffusion of innovation, System dynamics	Utility, User response time, Network interactions, Payment platform brand, Understanding user needs.
Shin and Lee (2021)	Technology acceptance model	Acceptability, Smart services and habit
MadadiNia, et al. (2023)	Bass diffusion model, System dynamic	Word-of-mouth advertising system, Mental norms, Technology image, User needs, Optimism, Insecurity, Productivity, Compatibility, Distrust complexity, Advertising effect.

3. Research methodology

This paper is applied research from an objective point of view. From the point of view of variable, quantitative, and qualitative research, as well as in terms of nature and method, it is classified as descriptive-analytical research. The data collection tools include questionnaires and interviews with experts who, due to the specialization of the subject, are experts with at least 18 years of work experience or university teaching in fields related to the research subject (information technology, electronic banking systems, and system dynamics). The Delphi method was used to extract the indicators. In this field, an exclusive interview was conducted with experts and senior managers of Mellat, Agriculture, and Resalat banks, as well as the Deputy of Mobile Communications of Khuzestan Province Telecommunication Company. Data analysis was done using the system dynamics approach and Vensim software.

4. Research findings

4.1. Causal loop model

The causal loop model for the diffusion of NFC technology is drawn based on the variables extracted in the research background section and their relationships in Figure 3.

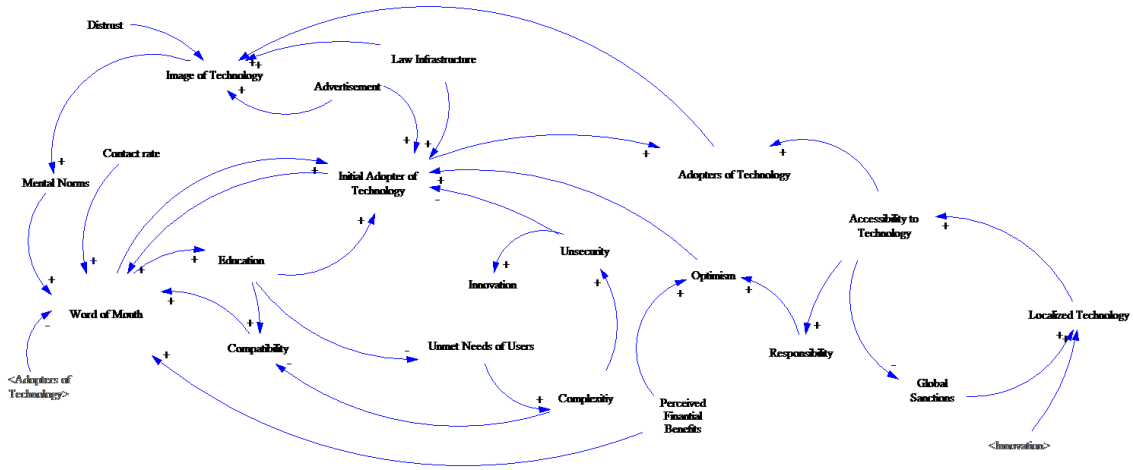

Figure 3. Causal loop model

4.2. The steps of system dynamics modelling

4.2.1. Dynamic hypothesis

The dynamic hypothesis describes the system's structure and explains what is happening dynamically (Koenig and Lewis., 2010). In the dynamic hypothesis, the authors have extracted the most important factors and ranked them according to their importance among all the factors in the research literature, using experts' opinions and the sensitivity analysis method. The dynamic hypothesis of this research is the explanation of the hypothesis as follows, which is tested by a simulated model:

Considering that the increase in the call rate increases word-of-mouth advertising, the improvement of word-of-mouth advertising will lead to the growth of potential adopters and the adoption rate of the technology. The technology rate variable's growth determines the changes in the actual number of technology adopters. With the increase in the growth rate of technology, the number of technology adopters has increased over time, which can give positive feedback to the word-of-mouth advertising variable. In the continuation of this cycle and the positive effect on the variable of stock of potential adopters and the variable of the growth rate of technology adopters, the authors will see an increase in the variable of technology adopters over time.

4.2.2. Stock-flow model

According to the causal loop model, the Stock-flow model was drawn, and the mathematical equations related to each variable were written using Vensim software. The Stock-flow diagram is shown in Figure 4.

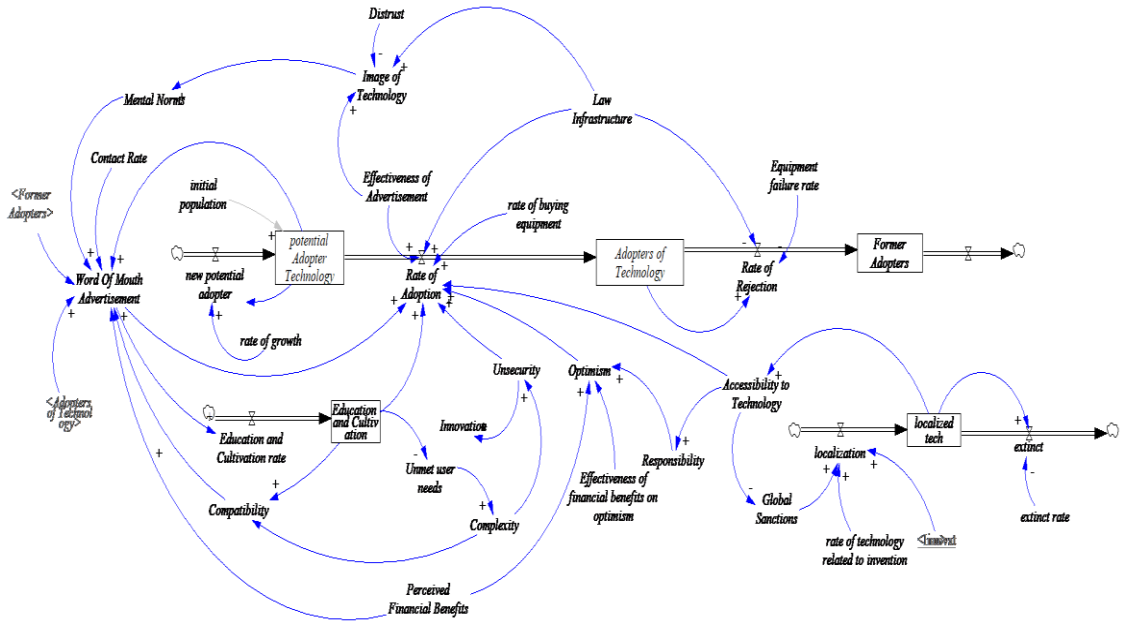

Figure 4. Stock-flow model diffusion model of NFC technology in mobile payment system

4.3. Model validation and simulation

After simulating the system dynamics model and before creating a scenario and relying on its results, validation should be done on the developed model. The most important step in determining the validity of the model designed in this research is judging its appropriateness. With the desired goal and after completing the stages of its design and implementation, the model was given to the expert group consisting of experts related to the subject and experienced senior managers in banking and economic institutions, information technology managers, and university professors to check the validity. Then, in order to confirm the validity of the presented model, since the NFC technology has not been seriously implemented in the country, first simulated the model for POS technology and issued bank cards; after confirming the validity of the model with various types of the methods, parameters of the model are set based on the NFC technology and the scenario analysis has been done regarding this type of technology.

4.3.1. Reference behavior reconstruction test

As seen in Figure (1), real data from 2015 to 2022 regarding the number of people who use bank cards have been compared with simulation results. The comparison of the results found that the model could reasonably simulate this reference variable's behavior to a reasonable extent.

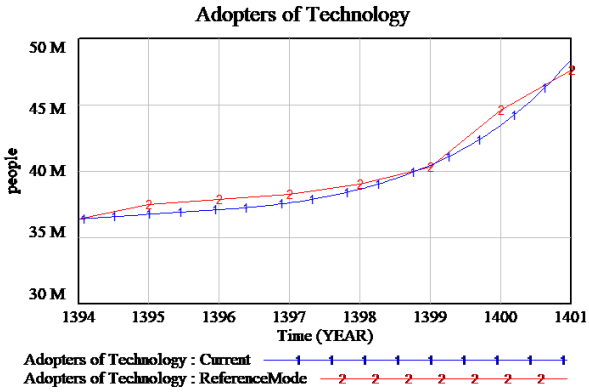

Figure 5. Comparing the real data and the variable simulation value of people that using bank cards

4.3.2. Structure verification test

The structure verification test evaluates the completeness and correctness of the model structure. The presented model's formulas for the variables are written and completed correctly, so the model can be implemented correctly. The implementation of the model shows that it is structurally free of defects, which has been confirmed using Vensim PLE software. The results presented in Figure 6 indicate the validity of the model.

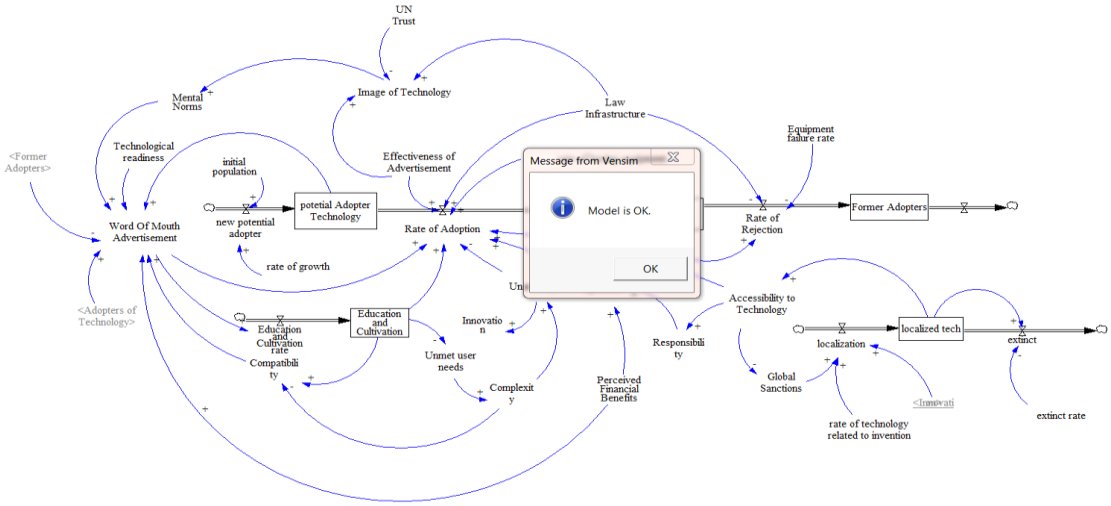

Figure 6. Checking of the model validity in the structural evaluation test with the Vensim software

4.3.3. Dimensional consistency test

The basic issue in this test is the equality and balance of the dimensions of the variables in all the equations used in the model. If all the selected units for the variables and fixed values in the model are correctly selected using the Vensim software, the correctness of the selected units can be evaluated by performing a dimensional verification test. If one of the selected units is not used correctly, it is impossible to confirm this test by the software, and incorrect units are shown as errors. According to the implementation of the designed model in Vensim software

and the results received, as seen in Figure 7, this model has been confirmed in terms of dimensional compatibility.

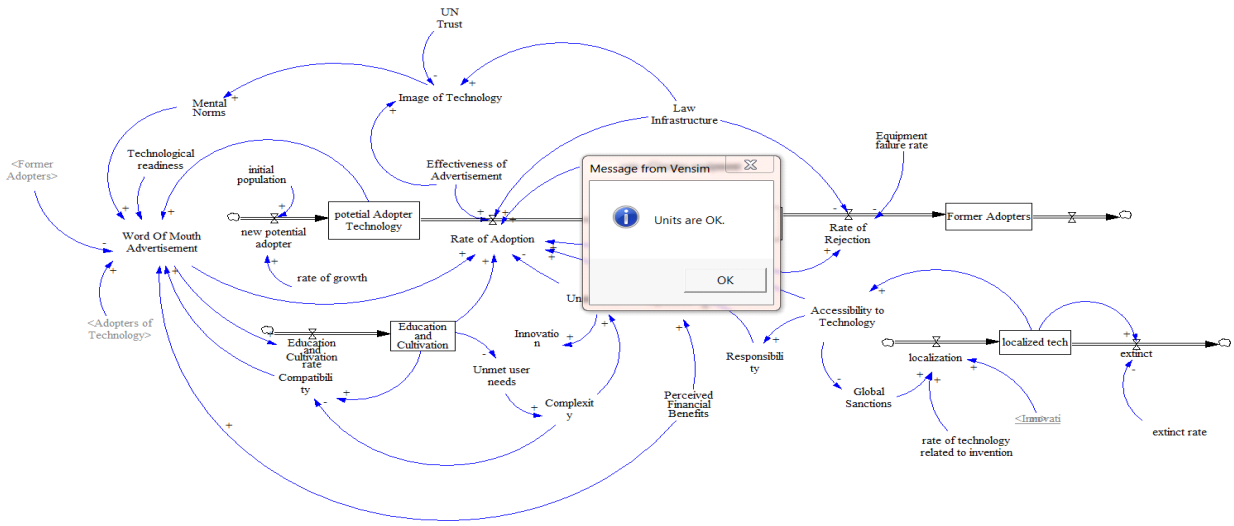

Figure 7. Examining the validity of the model in dimensional compatibility test with the vensim software

4.3.4. Limit condition test

In this part, the authors have examined the model's input variables under different values. The results showed that the model had reasonable behavior under certain conditions, and by observing the results of these changes in the input variables, practically no unreasonable behavior was observed. Therefore, the model's validity is confirmed in terms of this test. For example, by increasing the rate of technology growth by five times, as the authors expect, the number of potential adopters is greatly reduced, and the number of actual adopters is increased by the same amount (Figure 2&3). The model simulation results also indicated the same behavior, and no unreasonable behavior was observed regarding the model variables.

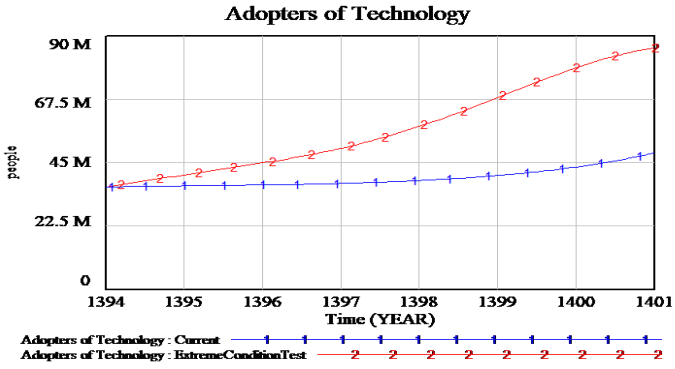

Figure 8. The results of the limit condition test of the simulated model

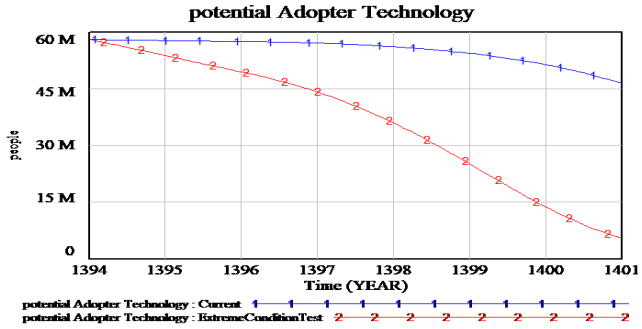

Figure 9. The results of the limit condition test of the simulated model

4.3.5. Boundary adequacy test

In this test, attention is paid to the structural relationships necessary to satisfy the purpose of the model, and this question must be answered: "Is the overall level of the model appropriate and all the related structures, including the variables and feedback effects that are necessary to investigate the problem?" Does it include the research objectives? Is it appropriate to the research objectives? Although it is almost impossible to deal with all the details and dimensions of the diffusion of NFC technology in the mobile phone payment system in Iran, and it requires building a model as big as human minds and the real world around them, the answer of the group of experts to this question, considering According to the dynamic hypothesis, the objectives of the research and the results of the implementation of the model were satisfactory.

4.3.6. Apparent validity test

This test examines the model's validity in terms of appearance so that the following questions can be answered in addition to compatibility with the real system: 1) Is the model structure similar to the real system? 2) Does the model provide a recognizable representation of the real system? 3) Is there a reasonable fit between the model's feedback structure and the real system's characteristics? The answers of the group of experts to all questions were positive, and the model's compliance with many previous researches on this matter and the effects of increasing the spread of NFC technology in the mobile payment system in Iran were quite evident.

4.4. Scenario planning

Identification of key parameters for scenario development: In this part, a sensitivity analysis was done on the parameters defined in the model to rank and identify the key factors. The impact of parameters on Technology Adopters is listed in Table No. 2.

Table 2. Ranking of the influence of different parameters on the variable of the technology adopters

NO	Variable
1	Contact rate
2	Early adopters
3	Legal infrastructure
4	Education and cultivation
5	Advertisement
6	Purchase of equipment
7	Lack of trust
8	Technology abandonment rate

4.4.1. First scenario: continuation of current conditions

After confirming the model's validity in terms of structure and behavior and setting the parameters related to bank payments based on NFC technology, the scenario analysis for the next ten years of this technology (1402 to 1412) will be done. According to Table 3, the parameters related to this technology are assumed to be similar to bank cards in the current conditions, and the scenario has been analyzed[1].

Table 3. Values of parameters affecting the diffusion of NFC

NO	Variable	Value in the first scenario
1	Contact rate	0.78
2	Early adopters	500,000
3	Legal Infrastructure	0.6
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4
6	Purchase of equipment	0.5
7	Lack of trust	0.7
8	Technology abandonment rate	0.35

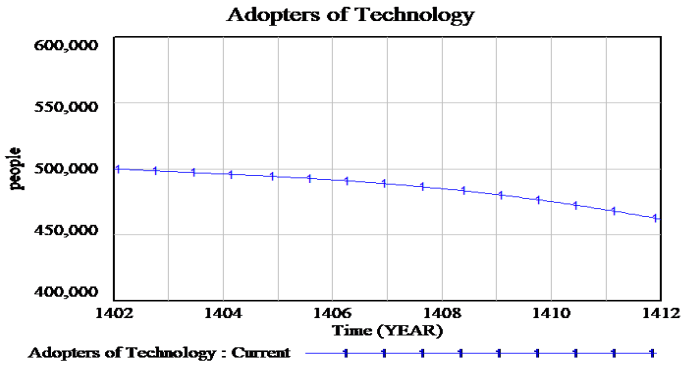

Figure 10. Reduction of technology adopters due to the implementation of the first scenario

As seen in the scenario of continuing current conditions, NFC technology, assuming stability in model simulation parameters in the past, will face a decline in diffusion, and the number of

1 Qualitative variables have been converted into quantitative values using a Likert-scale questionnaire or experts' opinions.

technology adopters will gradually decrease (Figure 6). Therefore, the following parameters were applied in the second scenario to expand the use of the mentioned technology.

4.4.2. The second scenario: improving the legal infrastructure, improving the effectiveness of advertising, and increasing trust

Due to the decline in the number of technology adopters in the first scenario, changes are made to the variables that influence the spread of technology. Therefore, to spread and expand the mentioned technology, the authors have improved legal infrastructure, advertising, and trust variables in the second scenario (according to Table 4).

Table 4. Parameters applied in the second scenario

NO	Variable	Value in the first scenario	Value in the second scenario
1	Contact rate	0.78	0.78
2	Early adopters	500,000	500,000
3	Legal infrastructure	0.6	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)	(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4	0.6
6	Purchase of equipment	0.5	0.5
7	Lack of trust	0.7	0.35
8	Technology abandonment rate	0.35	0.35

As seen in Figure 11, the number of technology adopters is increasing compared to current conditions, and technology diffusion is significantly improving.

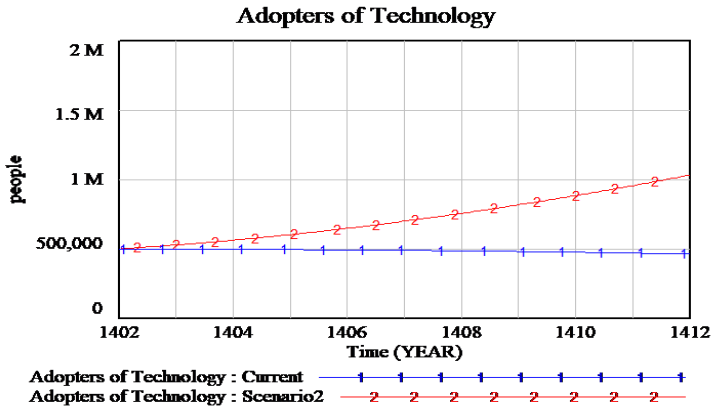

Figure 11. Increase of technology adopters up to 1,050,000 users in the second scenario

4.4.3. The third scenario: focusing on education and culture in addition to improving the parameters of the second scenario

In this scenario, all parameters of the second scenario have improved, and special attention has been paid to education and culture. According to Table 6, the number of technology adopters changes when the input rate for education and culture changes (Figure 12).

Table 5. Parameters applied in the third scenario

NO	Variable	Value in the first scenario	Value in the second scenario	Value in the third scenario
1	Contact rate	0.78	0.78	0.78
2	Early adopters	500,000	500,000	500,000
3	Legal infrastructure	0.6	0.9	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)	(0.05+Word of Mouth Advertisement/5.8e+007)	2*(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4	0.6	0.6
6	Purchase of equipment	0.5	0.5	0.5
7	Lack of trust	0.7	0.35	0.35
8	Technology abandonment rate	0.35	0.35	0.35

After the changes made to the parameters in Table 5, the following results emerge regarding the behavior of the model variables: education and culture do not considerably influence the number of technology adopters.

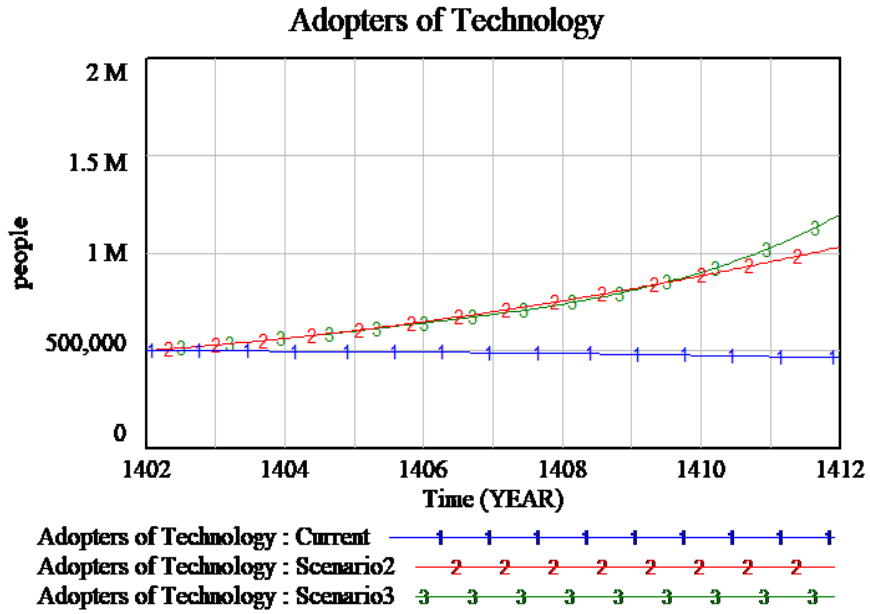

Figure 12. The increase of technology adopters 1.200.000 users in the third scenario

4.4.4. The fourth scenario: improving the early adopters in the fourth scenario

Assuming that the changes made to the parameters of the previous scenario are permanent, we assume that the authors will double the number of early adopters of the technology simulation, which was half a million in the previous scenario formulation (Table 6).

Table 6. Parameters applied in the fourth scenario

NO	Variable	Value in the first scenario	Value in the second scenario	Value in the third scenario	Value in the fourth scenario
1	Contact rate	0.78	0.78	0.78	0.78
2	Early adopters	500,000	500,000	500,000	1,000,000
3	Legal infrastructure	0.6	0.9	0.9	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5 .8e+007)	(0.05+Word of Mouth Advertisement/5 .8e+007)	2*(0.05+Word of Mouth Advertisement/5 .8e+007)	2*(0.05+Word of Mouth Advertisement/5 .8e+007)
5	Advertisement	0.4	0.6	0.6	0.8
6	Purchase of equipment	0.5	0.5	0.5	0.5
7	Lack of trust	0.7	0.35	0.35	0.35
8	Technology abandonment rate	0.35	0.35	0.35	0.35

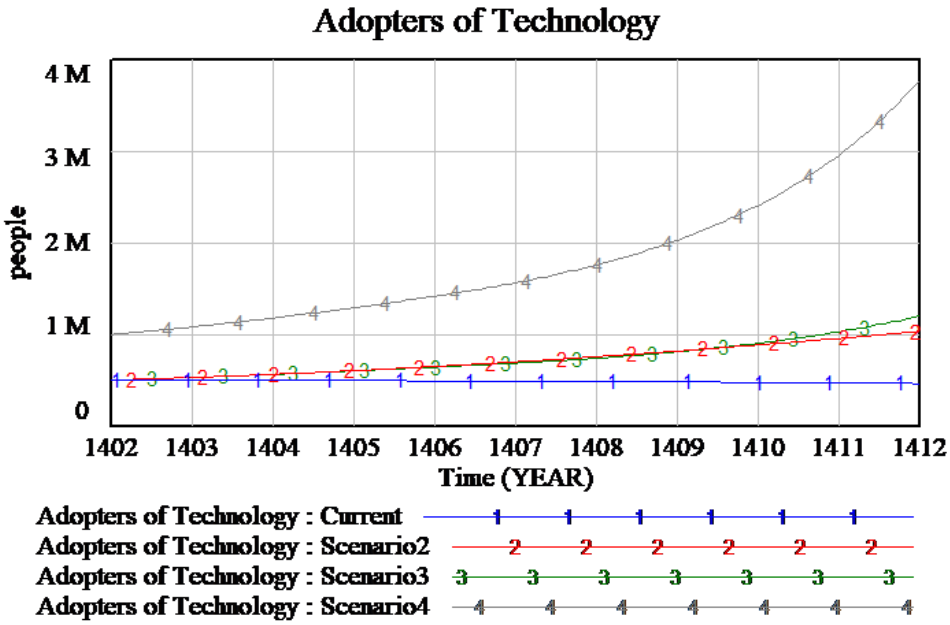

Figure 13. The increase of technology adopters up to 3.800.000 users in the fourth scenario

As shown in Figure 13, the initial number of people using NFC technology greatly impacts the growing trend of actual technology adopters. The results of the last scenario have also shown that the successful diffusion of NFC technology requires simultaneous actions in the four areas of advertising, reducing distrust of the technology, facilitating the legal infrastructure, and increasing the initial number of users of the technology. The summary of the scenarios can be found in Table 7.

Table 7. Definition of the four scenarios examined in the research

Scenario	Explanation of the scenario	The number of technology adopters in 1412
First	Continuation of the current process according to the bank card parameters	462,000
Second	Reducing lack of trust in technology, increasing advertising effectiveness, improving legal infrastructure	1,032,000
Third	Increasing the amount of education and culture	1,197,000
Fourth	Increasing the number of early technology adopters	3,774,000

4.5. Managerial insights.

According to the presented model, if the banks, financial and credit institutions, and other government institutions that influence the implementation of this technology are willing, in the not-so-distant years, the spread of this technology can be felt tangibly at the community level. The implementation and dissemination of this technology require a positive managerial attitude and perspective at the macro level of the country, the efforts of public and private institutions, as well as the implementation of laws and policies in order to ensure the security of users in the use of this technology by policymakers and legislators. The growth and spread of this technology depend on banking institutions, companies providing payment services, and customers. As the security provided in the provision of services increases, more customers will use this technology. With the increase in customers, banking institutions and service providers will be encouraged to install devices equipped with this technology more in society, and this cycle will continue as a self-reinforcing circle.

5. Conclusion and discussion

This study first presented the dynamic hypotheses as a causal progression diagram. Then, the stock variables of the model were identified, and the stock flow diagram was drawn. Subsequently, the mathematical relationships between the variables were entered into the model (Appendix 1), and the created model was evaluated and confirmed with validation tests. Next, the scenario analysis based on predicting the behavior of the model variables in the next ten years was performed, and the results were presented. As part of the reference behavior reconstruction test, the model simulated with an accuracy of over 98% the behavior of the number of card reader network operators from 2014 to 2022. After confirming the validity, a sensitivity analysis was performed to identify and rank the model's parameters. In the end, four scenarios were analyzed by adjusting the parameters for NFC technology.

The results of this study show that NFC technology will not only fail to develop but will also decline if it is developed according to the card banks' method. In order to successfully spread

this technology, the categories of advertising, legal infrastructure, education and culture, and early adoption of the technology must be considered simultaneously.

5.1. Limitations of the research

One of the limitations of most studies conducted using the system dynamics approach is the effects of variables and other parameters on the model making, which is limited according to the system boundary and its influence and the internal mechanism of the model. In this study, some parameters are assumed to be exogenous due to the large number of variables influencing the technology diffusion model.

Another limitation relates to some qualitative variables whose influence on the system under study is obvious. For example, legal infrastructure is a relatively defined variable for which an exact amount cannot be obtained.

Another limitation of the research is that we cannot use all the effective variables in technology diffusion. The increase in the number of influential variables in the diffusion of technology causes the expansion and complexity of the model. Therefore, it is suggested that in future research, in addition to the eight variables used for the scenario, new variables should be added to the model, and the model should be simulated again.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix 1:

Formulas written in the diffusion model of NFC technology in the mobile payment system

NO	Name of variables	Type of variable	Description	Initial value	Unit of variable	Equation of variable
1	Potential Adopter Technology	Level	Adopters who have the potential to use the technology.		People	new potential adopter-Rate of Adoption
2	Adopters of Technology	Level	Users who are using technology.		People	Rate of Adoption-Rate of Rejection
3	Former Adopters	Level	Users who were already using the technology.		People	Rate of Rejection
4	Initial population	Constant			People	58000000
5	New potential adopter	Auxiliary			People	initial population*rate of growth
6	Effectiveness of Advertisement	Constant	The passing of information by advertisement in social media, TV& …	0.4	Dmnl	0.4
7	Rate of Adoption	Auxiliary	The percentage of users who accept the technology and intend to use it.		people/ YEAR	0.5*(0.4* Accessibility to Technology+ 0.55* Effectiveness of Advertisement-.4*Unsecurity+ 0.5*Law Infrastructure +0.55* Education and Cultivation+ 0.5 *Optimism)* 0.55* Word Of Mouth Advertisement
8	Rate of Rejection	Auxiliary	The percentage of users who used technology until now, but no longer use it.		people/ YEAR	0.05* Adopters of Technology/Law Infrastructure
9	Rate of growth	Constant			Dmnl	0.08DELAY1({in} , {dtime})