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Comparison of Diffusion of Near Field Communication Technology in Mobile Phone and Electronic Payment Card Technology Using System Dynamics Approach

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ABSTRACT

According to the Central Bank of Iran statistics, around 300,000 electronic bank cards have been issued and made available to people. Based on this, the number of cards available to each user is estimated to be between 4 and 6. On the other hand, Near-field communication technology has been unveiled by some banks and financial institutions in the country, and some store card readers have also been equipped with this technology; despite many efforts, "near-field communication" technology for mobile phone-based payments has not been developed. In this research, the state of diffusion of near-field communication technology in the mobile phone-based payment system and its comparison with the technology of electronic payment cards from 2023 (1402 In Persian) to 2041(1420 In Persian) have been investigated and evaluated. The results show the growth of near-field communication technology and the significant decrease in electronic payment card technology.

Keywords

Near field communication technology, Electronic payment cards, Technology diffusion, System dynamics.

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1. Introduction

Electronic payment cards are among the most popular and common methods for conducting financial transactions and purchasing goods. The primary purpose of producing bank cards is to facilitate financial transactions, reduce risks associated with carrying cash, and decrease bank expenses (Mojdehi, et al., 2016). The first electronic payment card was issued in 1966 by Barclays Bank in Great Britain. In the following years, other banks, such as Bank of America and the National Bank of Germany, also began producing electronic payment cards. These cards are now used worldwide (Batiz-Lazo and Del Angel, 2018). NFC technology was unveiled in 2000 by Nokia, Siemens, and Samsung. This technology is based on "radio frequency identification" technology. Data can be exchanged between two devices equipped with this technology by bringing them closer together at a distance of approximately five centimeters. (Curran, et al., 2012). In many countries, electronic payment cards are being replaced by payment technology based on near-field communication technology (Samouti and Fathi, 2020). Southeast Asian countries, especially China, are among the leading countries in the use of communication technology. The nearest field is in mobile phone-based payment systems, and this trend is growing in European countries, but in our country, the use of electronic payment cards is still the leader in financial transactions. In this research, we seek to investigate the growth or decline of these two payment methods in the years between 2023(1402 In Persian) and 2041(1420 In Persian) in the country. In this article, the subject literature will first be discussed, including the history of electronic payment cards and payment systems based on mobile phones, NFC technology, and publishing technology. Then, the background of the research, the research method, and the research findings are written, and at the end, the selected scenarios, discussion, and conclusions are given.

2. Literature review

A bank card is an electronic payment device that enables the user to withdraw and deposit funds from a bank account. As a result of advancements in electronic payment technologies and methods, the bank card can now serve as a primary means of payment and withdrawal at all Iranian and international banks and exchanges.

2.1. History of electronic payment cards

Electronic payment cards are among the most significant developments in banking. These cards were first issued in the 1950s in America by the New York City Bank. The subsequent

advancement in electronic payment cards occurred in the 1960s when the "Bank America Card" was introduced to customers, allowing them the option to pay by card. Bank cards became widely accessible to the public during the 1960s and 1970s. In 1967, the Berkeley Bank of London also began issuing electronic payment cards. The 1970s, "Mastercard" entered the market in competition with "Bank America Card,periodIn the 1970s, Mastercard entered the market in competition with the Bank America Card, and in a short period, it became one of the most popular bank cards. With the emergence of serious competition between these two cards, other services and features were added to bank cards (Zumello, 2011). Despite the emergence of electronic payment cards in previous decades, the 1980s saw significant growth in their distribution and use. During this decade, with the introduction of internet payments, this technology became one of the most popular payment methods worldwide. Today, these cards enable access to banking services, online shopping, and international payments. With advancements in technology, bank cards have changed dramatically; they now utilize chip and PIN technology for enhanced safety and security (Thangavel, 2023).

Electronic payment cards are divided into two general categories: cards with magnetic strips and cards with electronic chips. With magnetic strip cards, customer and bank account information is stored on a black magnetic strip located on the back of the card. The information on the card is displayed by swiping the card in the card reader or inserting it into the ATM (Fancher, 1997). There are three slots on these cards. Usually, the first slot contains information such as the owner's name and account number. The second and third slots contain control information such as password, country code, authorized amount, and current currency. When the card-accepting company receives the card information, it measures the validity of the data in the magnetic strip, such as the correctness of the card number, the use of the card, and the limit of the card used (Iranicard.ir, 2023). In electronic payment cards with an electronic chip, information such as the bank account number, name of the cardholder, expiration date, and security information such as the three or four-digit CVV2 (Card Verification Value 2) or CVC2 (Card Validation Code 2) code, as well as the customer's bank information, is stored in the electronic chip and can be entered into the card reader or It is possible to make a transaction at an ATM. Bank card information can be transferred to the reader through an electronic chip. A bank card reader can read the information encoded in the electronic chip and use it to make a transaction (Mojdehi et al., 2007). Electronic chip technology is replacing magnetic tape due to higher security. Both electronic payment card technologies are currently still in use around the world. The electronic payment card is one of the most common payment tools that allows users

to make and conveniently make purchases faster, more securely, and more conveniently. One of the advantages of paying with a bank card is its faster speed than cash payment. Paying with an electronic payment card makes the shopping process quick and easy, and with its help, you can quickly pay for your purchase electronically (Krivoshia and Kurolo, 2018). Paying with a bank card is more secure, and in addition to reducing the risks of cash or check payment, it sends your personal information to the banking system in an encrypted form (Ming-Yen Tehu et al., 2013).

2.2. History of NFC (Near Field Communication) technology

"Near field communication" technology is a standard wireless communication method between electronic devices at close distances (less than ten centimeters). In late 2002, two companies, Philips and Sony, introduced NFC technology for non-contact communication. This technology was officially used in December 2003 with a bit rate of 106, 212, and 424 kbps and a central frequency of 13.56 MHz to communicate between two devices equipped with this technology. In 2004, Nokia, Philips, and Sony established the "Near Field Communication" association to promote this technology (Curan, Miyar, and McGarvey, 2012).

This technology is based on "Radio Frequency Identification" technology and works in two active and passive interfacepassive-interface communication modes. Based on the operation mode of the device, there are three methods and: read, peer-to-peer, and card emulation. The first of these modes allows passive reading and exchange of data stored on compatible carrier tapes such as NFC tags. In the card emulation mode, the data stored in the device can be read using an external reader such as a store card reader. Peer-to-peer mode includes connecting two separate devices equipped with this module. The two-way communication of these devices enables the active exchange of information between them (Leong et al., 2013). NFC protocol can realize a communication network using devices equipped with this technology. The exchange of information between systems also requires at least an agreement between the exchange parties about the exchange codes and data structure (Mohandas et al., 2015).

NFC technology suits small payments and crowded places with high transaction rates. On the one hand, the shortness of the communication time in this technology makes the payment process as fast as possible in such places. On the other hand, its short range ensures the security of the transaction and users' data and prevents the interference of the transaction of several users. It prevents each other (Mehrnezhad et al., 2015). Due to the newness of this technology, payment service providers based on NFC are mainly creating platforms. They are suitable for

the broad application of this method. On the other hand, most mobile phone manufacturers have provided phones with the capability of this technology, and it is expected that in the coming years, most of the mobile phones produced will have this capability.

2.3. Technology diffusion

The word dissemination means spreading information, technologies, innovations, behaviors, beliefs and diseases among the population. These cases can be modeled using the diffusion model among the target society. In the classical definition, diffusion includes innovation transmitted through specific channels over time between members of a social system (Rogers, 2003). In publishing, the target society is divided into two parts. The first group is the group that is aware of information, technology, innovation, etc., and the second group does not have any awareness or knowledge about the mentioned items. Over time, the second group is reduced and added to the first group (Page, 2018). Therefore, diffusion is a social process among people in response to learning innovation, such as a new evidence-based approach to expand or improve a service or product (Dearing and Cox, 2018).

Diffusion of technology has been used experimentally in various disciplines over the past years, is evolving, and continues to be applied to emerging innovations and social issues (Dearing and Meyer, 2006). Agriculture, medicine, education, communication, and marketing are among the various fields in which technology diffusion has been applied (Greenhalgh et al., 2005). Technology diffusion has been used for various studies on mobile applications, such as understanding customer acceptance of mobile payment systems (Shirtzet al., 2010), and social network adoption through diffusion theory (Span, 2022). In another study, they studied the dissemination and acceptance of online education for students during COVID-19 disease (Raman et al., 2022; Lee and Fanguy, 2021).

2.4. Research background

2.4.1. Background of external researches

Polasik et al. (2013), in research they conducted in the field of payment methods in Poland, found that payments based on NFC technology have higher time efficiency than other payment-researched payment methods in Poland and that payments based on NFC technology are more time efficient than other methods. In other research, Karsikko (2015) focused on identifying the drivers and inhibitors of mobile payment diffusion among Finnish consumers. The primary findings of this study indicate that mobile payments were perceived as a relatively positive

phenomenon; however, security emerged as a major concern compared to card payments. The results underscore a favorable attitude towards mobile payment acceptance. Yang et al. (2015), in research titled "Understanding Perceived Risk in Mobile Payment Acceptance," found that compatibility has the most significant impact on the intention to use mobile payment services. Sajid & Hedara (2016) investigated mobile phone payments utilizing NFC technology in Norway. The results and hypotheses from this research confirm that mobile payments using this technology are easy for consumers to use and effective for the intended purpose. Oliveira et al. (2016), in a study titled "Mobile Payment: Understanding the Determinants of Customer Acceptance and Intention to Recommend the Technology," discovered that compatibility, security, performance expectations, innovation, and social advertising significantly influenced mobile payment acceptance and intent to recommend the technology.

In other research, Subramanian (2017) examined the factors affecting the use of mobile phone payment systems based on near field systems based on near-field communication in supermarkets. He found that transaction speed, advertising, security, legal infrastructure, call rate, and word-of-mouth advertising can affect users' use of mobile payment based on NFC technology. In a study, Luna et al. (2017) examined the adoption of NFC technology for mobile phone payments in Brazil. The findings show that attitude, personal innovation in information technology, advertisingintention to use, and technical and legal infrastructure determine the purpose of using this technology for payment. Liébana-Cabanillas et al. (2018), in their supplementary research, published an article with the topic analysis of user acceptance of mobile payment systems in social networks, and in it to explain acceptance, legal infrastructure, and social advertising were included in the technology acceptance model. The merged results showed that companies results showed that companies could consolidate their business model using alternative payment systems resulting from new technical developments. Stanivuković et al. (2018) conducted a research titled. Predicting the demand of users of near-field communication based on mobile phones in the Serbian market. They considered risk, reliability, compatibility, advertising, legal infrastructure, and technology limitations. Existing migration cost, innovation, and personality were investigated.

Kawshalya (2020) evaluated the factors influencing the slow adoption of payment services based on near-field communication from the perspective of Sri Lankan customers and service providers. The research framework included nine independent factors and two mediating factors. A survey was distributed among consumers to identify the factors affecting their adoption of NFC-enabled payments. Structural equation modeling was used to analyze the

collected survey data. The research findings demonstrate that only the perceived ease of use positively influences the adoption of NFC-enabled payments. Compatibility, awareness, and the intention to use directly affect perceived ease of use; consequently, they indirectly positively impact the adoption of NFC-enabled payments in Sri Lanka. Technical issues such as limited battery power of point-of-sale (POS) devices, uncertainty regarding consumer transaction security, associated initial and recurring costs, and inadequate government regulation were identified as factors contributing to the slow adoption of NFC-enabled payments from the service providers' perspective. Li and Zheng (2023), in their research comparing cash payments, bank card payments, and mobile payments, found that factors such as word-of-mouth advertising and optimism driven by the image of technology significantly enhance users' willingness to utilize technology-based mobile payments compared to other payment methods. Hamzah (2023), in his research conducted during the COVID-19 pandemic, discovered that the use of NFC technology and mobile phones for purchasing goods and services has increased, and users are inclined to adopt these methods to prevent contracting the virus. They prefer not to use traditional payment methods or contact cards.

They found that factors such as risk, use and traditional resistance can prevent the spread of mobile payment technology. Still, In another study conducted by Madady Nia et al. (2023), titled "Technology Diffusion Model in NFC Technology in Mobile Phone Payment System in Iran," the proposed model and scenarios for the diffusion of this technology were presented. The results indicated that the call rate and legal infrastructure are significant factors in the spread of NFC technology. By 1420, this technology will be widely adopted in the country. In a separate study, Rabaai et al. (2024) examined the value of mobile payment from the perspective of resistance to technology. They found that risk, usage, and traditional resistance could hinder the spread of mobile payment technology. However, with the onset of COVID-19, this resistance has diminished, leading users to adopt contactless payment technologies to protect their health gradually.

2.4.2. Background of internal researches

In a study, Sarlak et al. (2013) found that despite the increasing trend of mobile efficiency in commerce, mobile banking was not well received. They stated that contrary to the growing trend of mobile phone efficiency in business, banking through mobile phones was not very well received, they found that trust in accepting electronic banking through mobile phones is effective in its acceptance. Mousavi Haghighi and Tajik (2014), in an article entitled Simulation

of the diffusion process of new products with the approach of system dynamics approach, using the bass diffusion model, investigated the technology diffusion process and word-of-mouth advertising, call rate, and quality as the most criticalessential variables. Influential on the publication introduced. Doosti (2014) in research entitled "Investigation of the infrastructure of NFC technology implementation in Qarz-al-Hasaneh Mehr Iran Bank," the primary purpose of this research is to investigate the legal and technical infrastructure of NFC technology in Iran's Qarz-al-Hasaneh Mehr Bank. The results of the tests showed that all the infrastructures for implementing this technology in this bank are above average. Karimi (2016) in the research conducted on the investigation of determining factors in the acceptance of mobile phone payment systems based on NFC by users, stated that despite the ability of this payment system, its use in the country has not yet expanded. The obtained results show that factors such as attitude, mental norms caused by image technology, trust, and usefulness have a positive effect on the intention to use this technology. Homayounfar et al.,(2017), in an article titled "Designing a Dynamic Model of New Product Development with an Emphasis on Bass Diffusion Theory," found that in addition to word-of-mouth advertising, the call rate and increasing the budget for research and advertising have an effect. It is more about attracting customers. Bastan et al. (2017), in their research, presented a simulation model of bank card acceptance by bank customers using the system dynamics approach. The results showed that improving the policies of increasing advertisements and services that can be provided effectively influences customers' intentions. A research study presented a simulation model of bank card acceptance by bank customers using the system dynamics approach. The results showed that improving the policies of increasing advertisements and services that can be provided effectively increases customers' intentions to use. Madady nia et al. (2023) in research entitled In their 2023 research titled "Drivers and Inhibitors of the Diffusion of NFC Technology in the Mobile Phone Payment System," Madady Nia et al. examined the factors influencing the adoption of NFC technology in mobile payment systems. They identified trust, social advertising, word-of-mouth advertising, and the image of the technology as the most critical factors impacting the spread of this technology. Drivers and Inhibitors of the Diffusion of NFC Technology in the Mobile Phone Payment System investigated the factors affecting the diffusion of this technology in the mobile phone payment system. trust, social advertising, word-of-mouth advertising, and the image of the technology were mentioned as the most critical factors affecting the spread of this technology.

3. Research methodology

After interviewing the elites and obtaining the dimensions and model components and indicators of the NFC technology diffusion model in mobile phone payment systems, the systems dynamics modeling method will be used for the quantitative research model in the next part. The system dynamics technique is based on information-feedback theory. It uses symbols to map business systems through diagrams and equations, and programming language is used for computer simulation. One of the most important goals of system dynamics modeling is to propose various policies to improve the system's performance and to choose the policy that provides the best implementation results (Chu et al., 2009). System dynamics technique based on existing feedback and delays show a picture of the system so that the dynamic behavior of complex physical, biological, and social systems can be better understood. The most basic principle expressed by system dynamics is that feedback and delays create the behavior of systems. The dynamics of system behavior are the result of the structure that governs the system (Faqih et al., 2013).

3.1. System dynamics

System dynamics were presented in the mid-1950s by one of the professors of the Massachusetts Institute of Technology named Forster as a new way to manage the performance of companies. He believed the human brain cannot interpret social systems' behavior with linear and one-way logic. Hence, multi-loop nonlinear feedback systems should be used to analyze various phenomena. By proving the efficiency of system dynamics and technological progress, the use of computer software to implement this method was expanded (Vennix et al., 1997).

System dynamics is a method for understanding, evaluating, and quantitatively and qualitatively analyzing the nonlinear behavior of complex systems over time. System dynamics is one of the efficient approaches to analyzing dynamic systems in various fields such as management, economics, biology and engineering. To define the model and simulate the behavior of a phenomenon, the relationship between the parameters in that phenomenon should be determined. In dynamic systems, each decision's output will affect its future input. System dynamics is considered as one of the branches of systems theory. In this approach, concepts such as feedback loops, accumulation-flow diagrams, and time diagrams display time-based changes and interactions between different system parts. Finally, the behavior pattern of the system is obtained in the specified time interval.

4. Research findings

According to the research background and experts' opinions, the variables of NFC technology users, magnetic card users, and new potential users as stock variables and variables of birth rate, death rate, contact rate, legal infrastructure, image of WOM (word of mouth) advertising technology WOM, the effect of media advertising and trust were used in model building and simulation. The causal loop diagram is shown in Figure (1).

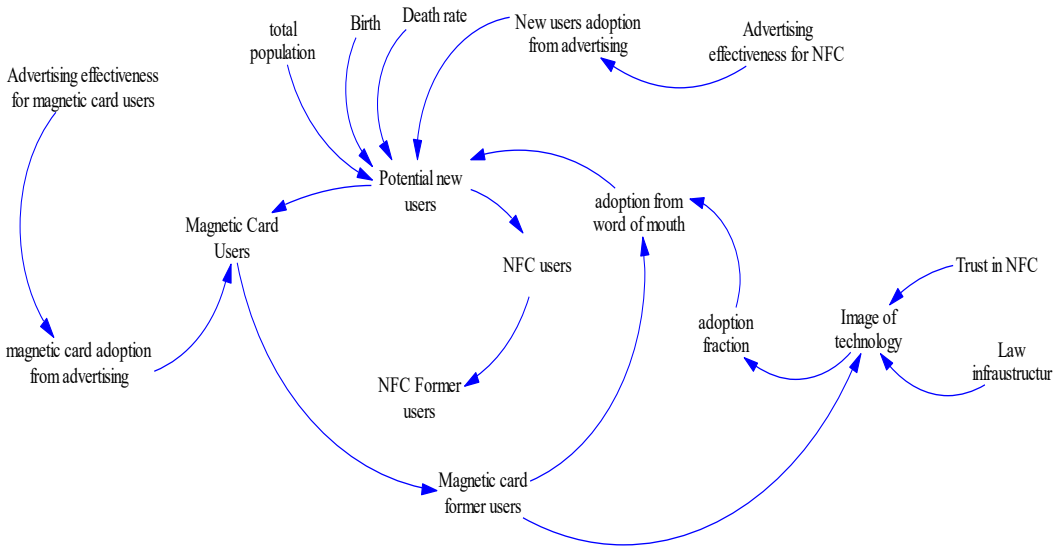


Figure 1. Causal loop diagram

Magnetic card users, NFC users and potential new users are the state variables in this model. The stock-flow model designed in Vensim software is shown in Figure (2).

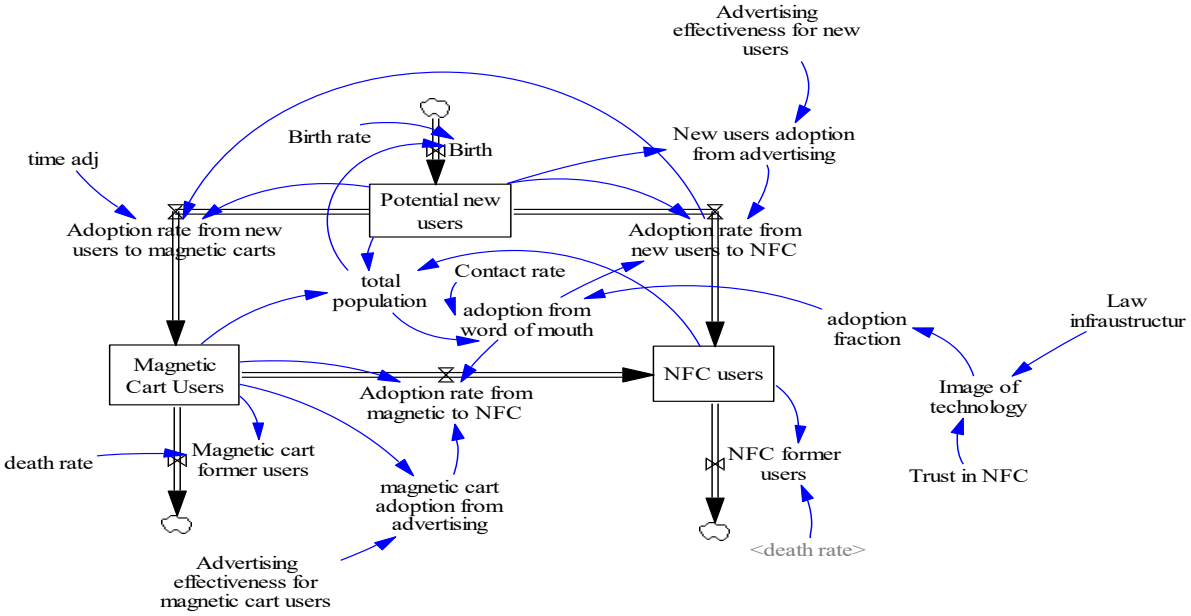


Figure 2. Stock-flow diagram of the integrated diffusion model of NFC technology and magnetic payment cards

The equation of variable is shown in Table1.

Table 1. Equation of variable

Variable	Equation
Potential new users =	Birth-Adoption rate from new users to magnetic carts-Adoption rate from new users to NFC
Magnetic Cart Users =	Adoption rate from new users to magnetic carts-Adoption rate from magnetic to NFC-Magnetic cart former users
NFC users =	Adoption rate from magnetic to NFC+Adoption rate from new users to NFC-NFC former users
Adoption rate from new users to magnetic carts =	Potential new users/time adj-Adoption rate from new users to NFC
Adoption rate from new users to NFC =	New users adoption from advertising+adoption from word of mouth*Potential new users
Adoption rate from magnetic to NFC =	Magnetic Cart Users*adoption from word of mouth+magnetic cart adoption from advertising
Magnetic cart former users=	death rate*Magnetic Cart Users
NFC former users=	death rate*NFC users
Birth =	total population*Birth rate
New users adoption from advertising =	Advertising effectiveness for new users*Potential new users
Image of technology =	Law infraustructur+Trust in NFC
adoption from word of mouth =	Contact rate*adoption fraction/total population
total population =	Magnetic Cart Users+NFC users+Potential new users
magnetic cart adoption from advertising =	Advertising effectiveness for magnetic cart users*Magnetic Cart Users

4.1. Scenario analysis

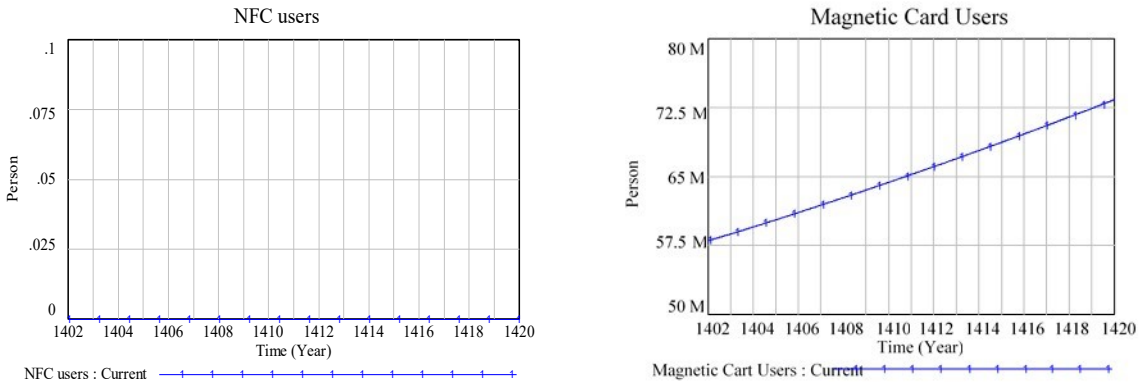
According to the model presented in Figure (1) and experts' opinions, four influential variables were used as key variables in the scenario development to investigate the diffusion of NFC technology and the decline of payment technology based on magnetic payment cards. Below, we describe selected scenarios.

4.1.1. First scenario: Continuation of current conditions

In the first scenario (Table 2), it is assumed that no action will be taken regarding the dissemination of NFC technology, and the process of using magnetic payment cards will continue with the previous process. The results show that the number of users of NFC technology have not grown at all (Figure 3-a), but the number of users of magnetic payment cards will reach 73 million people according to the population growth (Figure 3-b).

Table 2. Defined parameters regarding NFC technology in the simulation of continuing current conditions

NO	Parameters	Value in the continuation simulation of current conditions
1	Advertising effectiveness for new users	0
2	Advertising effectiveness for magnetic cart users	0
3	Trust in NFC	0
4	Law infrastructure	0



a: NFC technology adopters b: Acceptors of magnetic cards

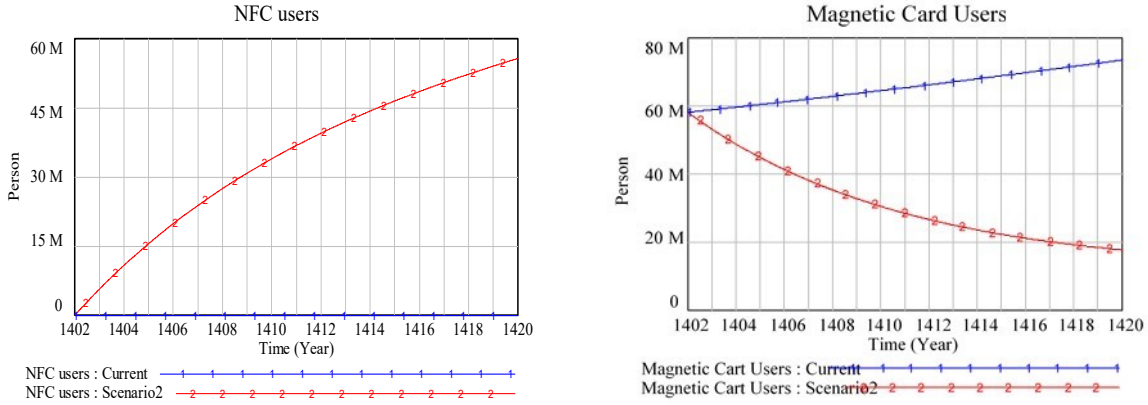
Figure 3. Simulation results in the first scenario

4.1.2. The second scenario: Improving the legal infrastructure and trust in conditions of low advertising effectiveness

In this scenario (Table 3), trust and legal infrastructure have reached their maximum value, and the effect of advertising on new users and the effect of advertising on magnetic cards are at their minimum value. In this situation, the adoption of NFC technology has grown to about 55 million users (Figure 4-a), and the adoption of magnetic cards has decreased to about 18 million users (Figure 4-b).

Table 3. Defined parameters regarding the NFC technology in the simulation of the second scenario

NO	Parameter	The value in the simulation of the first scenario	The value in the simulation of the second scenario
1	Advertising effectiveness for new users	0	0.1
2	Advertising effectiveness for magnetic cart users	0	0.1
3	Trust in NFC	0	1
4	Law infrastructure	0	1



a: Near field communication technology adopters b: Acceptors of magnetic cards

Figure 4. Simulation results in the second scenario

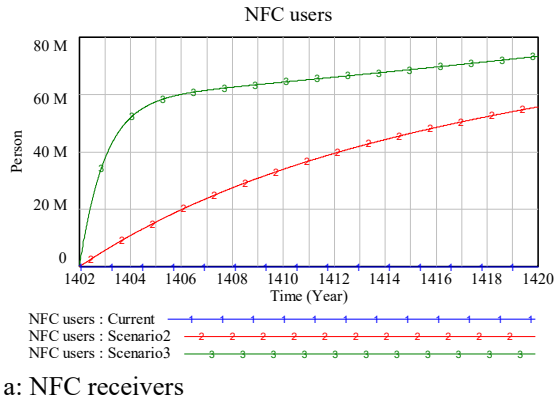
4.1.3. The third scenario: Improvement of legal infrastructure, trust in conditions of high effectiveness of advertising

In the third scenario, the four factors selected are increased to their maximum value, and in this condition, the development status of NFC technology and the decline of technology based on magnetic payment cards are evaluated.

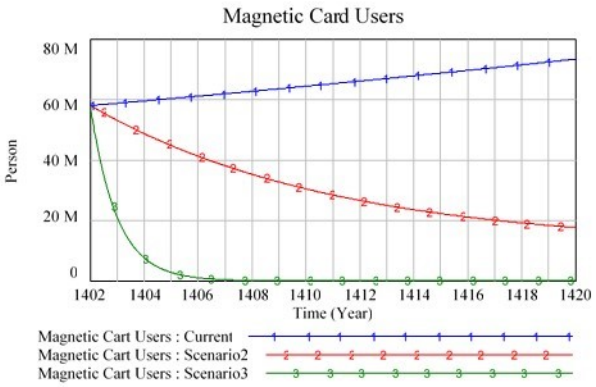
According to the parameters written in Table 4, the rate of growth of NFC technology has been exponential and very fast, reaching almost 63 million users by 2029 (1408 In Persian) and more than 73 million users in 2041 (1420 In Persian) (Figure 5-a). In the same situation, bank card acceptors have gradually decreased, reaching almost zero since 2029 (1408 In Persian) (Figure 5-b) and accounting for a few users.

Table 4. Defined parameters regarding NFC technology in the simulation of the third scenario

No	Parameter	The value in the simulation		
		First scenario	Second scenario	Third scenario
1	Advertising effectiveness for new users	0	0.1	1
2	Advertising effectiveness for magnetic cart users	0	0.1	1
3	Trust in NFC	0	1	1
4	Law infrastructure	0	1	1



a: NFC receivers



b: Card acceptors

Figure 5. Simulation results in the third scenario

5. Discussion and conclusion

The two technologies mentioned in the research have features that can have their fans among users. Payment card technology benefits from ease of use, but maintaining a large number of them carries many risks. On the other hand, NFC technology has the feature of high transaction speed, and there is no need to maintain multiple bank cards. Given the emergence of NFC technology in recent decades and the expansion of its use in electronic banking, the use of this technology is growing in many countries. Despite the many efforts made in our country to spread this technology, it has not been widely accepted due to factors such as trust, legal and

technical infrastructure, lack of a clear image of the technology, advertising, and many other things.

In this research, two technologies electronic payment cards and mobile payment technology based on NFC technology, have been examined and compared. According to the designed scenarios, the best scenario for expanding this technology as an alternative to electronic payment cards is the third scenario, which, according to Figures 7 and 8, will be replaced by 2027 (1406 In Persian), which is approximately three years from now. It can be done quickly. It will be possible, but given the relatively high population of elderly people and the lack of easy use of NFC technology by this segment of society, it is suggested to use the second scenario, which will carry out this replacement at a slower pace and a slower pace. The gentler slope of this research can to greatly help banks and financial institutions that have made great efforts in this direction in previous years but have not succeeded in expanding "NFC" technology in the mobile payment system.

One limitation of the research is the lack of data in the field of NFC technology. Another limitation is the lack of up-to-date data on electronic payment cards. After the diffusion of the NFC payment system and re-implementation of the model, it is possible to obtain a better output.

Considering the growth of technology and the spread of mobile phones equipped with NFC technology, it is suggested that after two years of implementing this technology in the mobile payment system, simulation based on new parameters, again and in case of using the second scenario which brought the gradual growth of NFC technology, the policies should be implemented based on the third scenario which was faster.

Disclosure statement

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

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