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Conceptual Modeling of the Internet of Things Implementation in Hospitals Supply Chain

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Abstract

Given the complexities of supply chain networks, the firms consider modern technologies as a potential factor to improve their supply chain performances. One of these technologies is the Internet of Things (IoT). Hence, the main purpose of this study has been to achieve the conceptual model of the IoT implementation in hospital supply chains. Considering the qualitative nature of the study, relevant articles were specified through library research and collecting the related literature. The outputs obtained were analyzed using the meta-synthesis method and the grounded theory. Then the selected articles were extracted and the grounded theory was used to obtain the conceptual model of the IoT implementation in hospital supply chains. The research results indicated that the model featured 7 main categories, 19 subcategories and 86 codes. The results present a conceptual model for the implementation of the IoT in hospital supply chains including an explanation of the main research category, drivers, prerequisites and enablers, environmental and contextual conditions, challenges, technology implementation strategies, and results and outcomes.

Keywords: Internet of Things; Supply Chain; Hospital Industry; Technology Implementation.

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Introduction

Nowadays, organizations are constantly moving away from simple environments toward dynamic ones (Duffy, 2001). In many cases, this evolutionary process has lead to various challenges impeding the sustainable development of the organizations (Ahmad et al., 2015). These unexpected issues have been entangled with the increasing global competition and have, in turn, forced firms to constantly revise their strategic priorities (Lockamy & McCormack, 2004). The competition is applied to organizational capabilities and the supply chain as well as every new product or service (Ahmad et al., 2015). According to Stadler and Kilger (2008), all supply chain processes (including upstream and downstream ones)0must2be aligned to8the customers' needs. Thus, coordination and collaboration are regarded as the two main pillars of each supply chain.

Information technology and communications are among the critical measures aiming at increased coordination within the supply chain. The emergence of the internet and electronic communications has made firms more responsive to their customers. Similar developments in other technologies have changed the market, providing a driving force to make changes in organizational structures. Therefore, the traditional supply chain management has been replaced by the electronic supply chain management. Future organizational structures will include features of the electronic supply chain where technological communications will link many companies and external performances. The result will be low-cost flexible partnerships that in turn will provide a sustainable competitive advantage.

The utilization of the IoT concept in the industrial field is one of the modern areas of information technology. The IoT is rapidly developing in today's world, mainly in the form of telecommunication scenarios (Wickramasinghe & Goldberg, 2004). The IoT is considered as one of the most up-to-date technologies in the new era of information and communication. The technology interconnects many of the physical world objects through housing them under the network. For example, Cloud computing has helped firms cope with challenges posed in systems of fault detection, tracking targets and automating management using information tools, smart-equipment (such as receivers, wireless sensor networks, etc.), middleware and under web software platforms (Qeysari et al., 2013). The IoT is used to increase productivity, competitiveness, and coordination throughout the supply chain (Wickramasinghe & Goldberg, 2004).

Given the complexities contained in supply chain networks, firms consider modern technologies as potential factors to improve their supply chain performances with the purpose of effective management of their complexities. New technologies and applications might be designed and developed but if users do not get involved and do not use it, the project has failed, thus, user acceptance is an undeniable indicator of any further implementation and development in any technological application. In other words, in order to increase the level of the IoT technology usage and user adoption, the emphasis on factors that can influence user acceptance should be raised (Taherdoost,H, 2019). This research has attempted to avoid entering the technical level of the "Internet of Things" but instead aimed at studying the phenomenon in applied and business levels.

The supply chains of healthcare-related products and services are regarded as the most crucial ones. They entail risk mitigations, reduced costs and higher levels of coordination. Nowadays reducing the risks and costs of healthcare services is deemed as a global priority. Technology and automation especially the IOT are potential contributors to reducing costs and risks as well as enhancing the coordination and collaboration throughout the related supply chains (Wickramasinghe & Goldberg, 2004).

The supply chain of the healthcare industry directly influences people's health and lives. It should be noted that medical errors are among the leading causes of death and damages occurred to patients. Bringing severe consequences for the patient and society, these errors are globally costly issues that require serious attention to be prevented. Based on the annual statistics for 1999, ninety-seven thousand (97,000) deaths recorded the 55 US states resulted from medical and hospital malpractices and the figure reached one-hundred and ninety-five thousand (195,000) deaths in 2003. Medical errors have incurred a cost of almost 37.6 to 50 billion dollars on American society annually. Preventable errors account for 17 to 29 billion dollars of the mentioned cost.

In 2006, Iran Medical Council and the Iranian Legal Medicine Organization received about 5,000 and 7,000 complaints respectively. These included medical errors in conducting technical measures and necessary steps that may have harmed or maimed the patient. Based on the research findings, most medication errors are committed by nurses when administering medicines to patients in hospitals. The studies indicated that 70 percent of the medical errors were preventable, six percent were probably preventable and 24 percent were unpreventable.

Thus, it cannot be expected to ignore the physicians' errors (Akhavan Behbahani, 2008).

The IoT applications through increased health smartness can lead to the development of some platforms providing patients and people requiring medical care with innovative services. These applications improve the quality of life for the people as well as promoting health, safety and easy access to medical and hospital services, ongoing cares and rapid support (Vermesan & Fries, 2014).

In short, the necessity of considering the coordination and collaboration in the supply chain management, impacts of the electronic supply chain management on performance improvement and the utilization of tools such as the IoT to enhance the effectiveness of healthcare and hospital services as well as improving their supply chain performances has led the researcher to address the conceptual modeling of the IoT implementation in hospital supply chains.

The Research Theoretical Background

The IoT concept firstly became pervasive through the projects of the Massachusetts Institute of Technology and its analytical journals. However, the term Internet of Things was coined by Kevin Eshtone in 1999 (Gubbi et al., 2013). Today, the term implies the integration of the physical world into the internet's virtual work. It means that IoT is a network interconnecting the information resources shared between the smart objects and market institutions. The network aims at increased efficiency and effectiveness for every service delivered to the customers (Keskin & Kennedy, 2015).

Since then, many theorists have exploited the term IoT to refer to the general idea of objects, especially everyday ones that were readable, detectable, locatable, addressable, and controllable through the internet. In this regard, they did not consider the type of communication (RFID, wireless, WAN, etc.) Everyday objects are not only the electronic devices that we use or technologically-developed products such as vehicles but also the objects that we normally do not consider electronic such as food and clothes (Perera et al., 2014). Regardless of the time and place, these objects of the real world must be capable of seamlessly integrating into the virtual world. In 2010, the number of physical objects and devices connected to the Internet was about 12.5 billion. Based on the Cisco company prediction, this figure will double to 25 billion by 2015. By 2020 the number of smart devices per person will be increasing reaching 50 billion (Bradley et al., 2013). Supply chain management is considered as one of the critical parts of an organization's management. The supply chain is responsible for coordinating all units from the initial stages such as supplying materials to the final stages like delivering goods and after-sales services. Supply chain management requires comprehensive reliable information platforms. Hence, it is of substantial importance to correctly exploit the integrated information systems such as the IoT. An instantaneous accuracy to cover this information acts as a facilitator factor, resulting in a more transparent progress process (Khodabakhshi et al., 2016).

One of the most distinct advantages of the IoT is its application during the supply chain management. The IoT can influence all processes of the supply chain. Many studies in the area of supply chain and logistics have acknowledged that the electronic systems are empowered by using the IoT, resulting in enhanced efficiency and effectiveness throughout the supply chain (Khodabakhi et al., 2016).

The IoT applications have a potential future market in the field of healthcare and eHealth (Vermesan & Friess, 2014). Fuhrer, Guinard (2006) investigated the use of RFID and other IoT devices in smart hospitals and how they are implemented. The IoT is effective in rectifying hospital system errors and improving hospital system applications in saving lives by identifying patients, hospital operations, counterfeit drugs, tracking equipment, patients, staff and documents, and providing a patient's smart drug portfolio. Qasemi et al. (2016) also prioritized ICT applications in the Iranian health sector based on sustainable development indicators. According to the research results, the most crucial applications in Iran are the applications of “chronic disease management”, “patient monitoring”, “pollution control”, and “diagnosis of disease”.

The Research Empirical Background

There are numerous international studies which have examined the supply chain of the healthcare industry as a specific model of the service supply chain. The following is a brief overview of these studies.

In a paper, Brennan (1998) explored the issues of integrating the supply chains of hospitals and healthcare centers. In a paper entitled “*Meta-synthesis stockless: A case study: Lessons for health-care supply chain integration*”, Rivard-Royer et al (2002) outlined different case studies regarding the integration of the two pillars of the supply chain in the healthcare industry. In the Massachusetts Institute of Technology, Descioli (2005) investigated hospital supply chains and their performance enhancements in a paper entitled “*Differentiating the hospital supply chain for enhanced performance*”. In their research, McKone-Sweet and colleagues (2005) examined and identified the healthcare system’s supply chain. Schneller and Smelters (2006) wrote a book on how to formulate the strategic management of the healthcare supply chain (in hospitals and the healthcare industry). In a review article, De Vries and Huijsman (2011) addressed the studies carried out on the supply chain management in the healthcare system, hospitals and health centers.

Bendavid and Boeck (2011) also examined the RFID application in order to improve the hospital supply chain management for high-value assets and cargo items. In their paper, they introduced using the "radio frequency identification" technology in hospitals as a good solution to improve supply chain management.

Based on the SCOR and Elam's models, Baltacioglu and colleagues (2007) presented a new service model of the supply chain in the healthcare industry. Consisting of all the supply chain elements, the model covered definitions of the management activities throughout the service supply chain (Information technology management, demand management, customer relationship management, supplier relationship management, capacity and resource management, order process management and service performance management).

Considering the research problem, theoretical and empirical backgrounds and the gap identified by the previous research, no study has yet addressed the conceptual modeling of the IoT implementation in hospital supply chains. Also, using the meta-synthesis method and the grounded theory for IoT implementation modeling, therefore, the present research aims to conceptually model the IoT implementation in hospital supply chains through explaining the main categories and subcategories as well as the codes of subcategories.

The IoT can facilitate service delivery to patients by increasing business intelligence in hospitals and medical centers (Roman et al., 2011). The IoT provides health improvement and disease prevention through ongoing monitoring of the activities of normal or susceptible individuals and helps empower patients. Businesses can also benefit from this innovative new market (Vermes & Fries, 2014). It can be said that the social problems of patients and those concerned about health are more easily remedied and their quality of life is improved, which contributes to the economic prosperity of the health sector (Haller et al., 2008).

Materials and Methods

Having a qualitative data nature, this research is classified as fundamental in terms of its aim. Suitable qualitative methods such as the meta-synthesis method and the grounded theory coding were used to extract the model and its dimensions and measures. Despite being two separated topics, the IoT concept and the supply chain enjoy an extensive number of the relevant articles. Implementing the IoT in hospital supply chains is a relatively new area involving qualitative studies with a wide subject distribution. In the present research, the meta-synthesis method was used as a suitable approach to achieve a comprehensive combination of factors constituting the IoT implementation model in hospital supply chains.

In this study, the researcher has aimed at discovering the basic accurate information on an uncertain phenomenon or situation. After analyzing the qualitative data by the meta-synthesis method, the researcher coded the basic concept through the grounded theory. The concepts were extracted based on open coding. Then, the axial and selective coding methods were applied to identify the subcategories and the main categories, respectively. These steps have led the researcher to describe the conceptual model of the IoT implementation in hospital supply chains.

Validity and Reliability of the Research Methods

For the validity and reliability of the meta-synthesis method, a method called the Centralized Assessment Selection Program (CASP (was applied to qualitatively assess the articles. According to this method, 10 questions were answered to evaluate the accuracy, validity, and significance of the qualitative studies. Once the questions were evaluated through the CASP method, the articles extracted were categorized as 25 good quality articles, five very good quality articles and eight excellent quality articles.

The reliability of the meta-synthesis method was measured by the agreement between the two codes; accordingly, another researcher separately coded the same text without being aware of the main researcher's codes. Similar codes would indicate high agreement between the two coders, implying the reliability of the method. The Cochen Kappa coefficient was used to calculate the coefficient of agreement between the two coders. In this study, the Kappa coefficient was obtained as 0.78, indicating a good level of agreement.

Results

In this research, the seven-step method by Sandelowski and Barroso was used. The time frame of the study has been from 1970 to 2019. The research was aimed at identifying and grouping the dimensions and components of the IoT implementation model in hospital supply chains. Both quantitative and qualitative methods were used, resulting in the model generation. Being performed in English, the study was on the criteria obtained and questionnaire production, data collection, and classification of results.

Through searching for the relevant keywords in the reputable scientific and research databases, the measures for collecting the articles aligned to the research area were conducted. The keywords used in the present research included the Internet of Things supply chain, Hospital Supply Chain, Modeling the Internet of things and Implementing the Internet of Things. The search resulted in 2402 keywords from English articles.

After revising the articles found, inconsistent articles were excluded based on the determined criteria. Inconsistent articles were ruled out through three steps. In the first step, articles with irrelevant titles were excluded. In the next step, the articles having relevant titles were selected and their abstracts were studied. The papers with the irrelevant abstracts were omitted. After studying and exploring the remaining articles, finally, 38 papers with rich content were identified and the rest was omitted.

Figure 1 shows a summary of the search results and the process of selecting the relevant articles. The searched and reviewed articles are associated with ScienceDirect, EBSCOhost, Scopus, ProQuest, IEEE, Emerald, and SID databases.

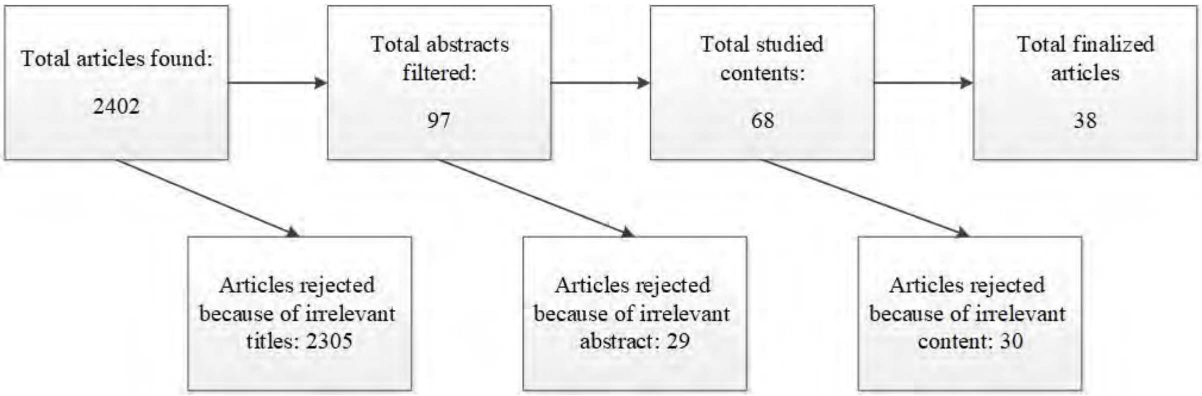

Figure 1. Summary of the search results and selecting of the relevant articles

The data obtained from the articles were categorized as follows:

1. Conceptual factors and components in each article;
2. Methods of implementing the Internet of Things;
3. Modeling the Internet of Things;
4. Internet of Things in the Supply Chains.

Throughout the research background, it was noted that different methods must be used for implementing the IoT due to the various purposes and its applications in different situations. In the present study, all the purposes extracted for implementing the IoT in hospital supply chains were addressed.

After studying the papers and results derived from the meta-synthesis method, the researcher used the open coding, the axial and selective coding methods in order to extract the basic concepts, subcategories and the main categories of the model, respectively.

Based on the research results, the conceptual model for implementing the IoT in hospital supply chains consists of seven main categories including "drivers", "challenges", "prerequisites and enablers", "environmental and contextual conditions", "implementation strategies", "results and consequences" and "the main phenomenon". The following is a detailed description of the model results through Figures 2 to 9.

As can be seen in Figure 2, the main category of "Drivers of the IoT Implementation in hospital supply chains" has two subcategories of "Hospital and Healthcare Industry drivers" - with three codes- and "Supply Chain General Drivers" with two codes.

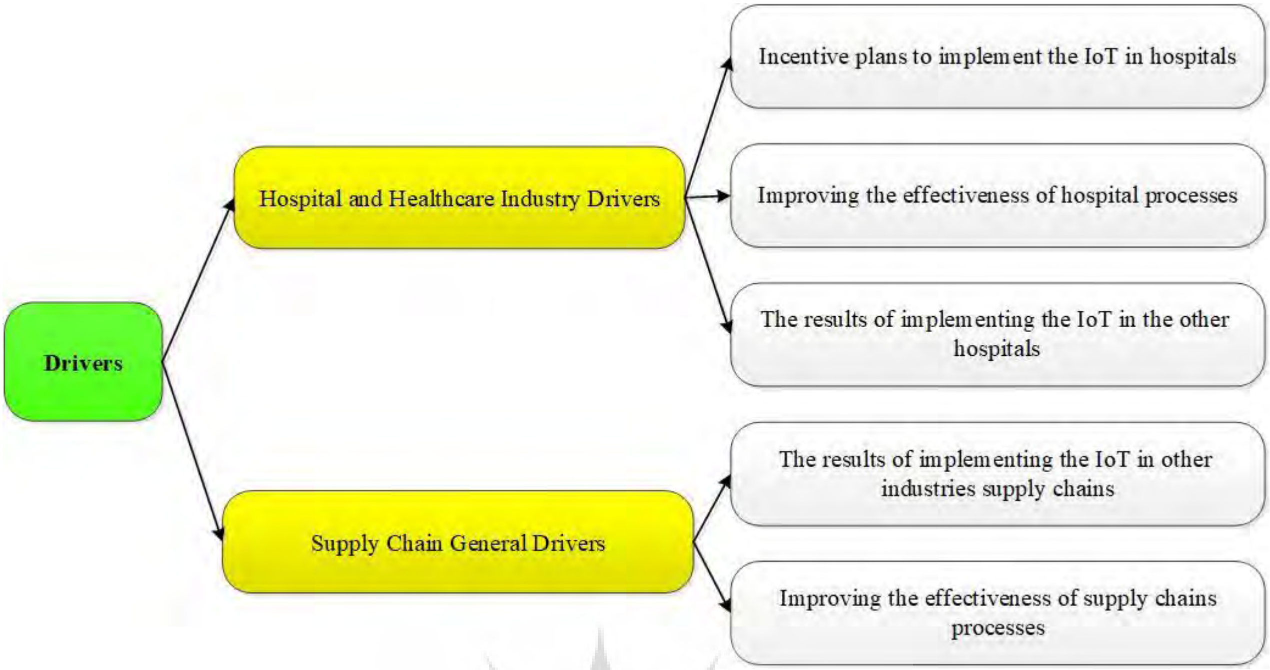

Figure 2. Criteria and codes of the category "Drivers"

As shown in Figure 3, the main category of "Challenges of the IoT Implementation in hospital supply chains" has four subcategories including the "Technological" subcategory with two codes, the "Privacy and security" subcategory with three codes, the "Legal and Regulatory" subcategory with three codes and the "business" subcategory with eight codes.

Challenges are the obstacles that impede the implementation of the underlying phenomena that influence the prerequisites and strategies for implementing the technology.

As presented in Figure 4, the main category of "Prerequisites and Enablers of the IoT Implementation in hospital supply chains" has two subcategories: "Technology Implementation Prerequisites" -with three codes- and the "Technology Implementation Enablers" subcategory with four codes.

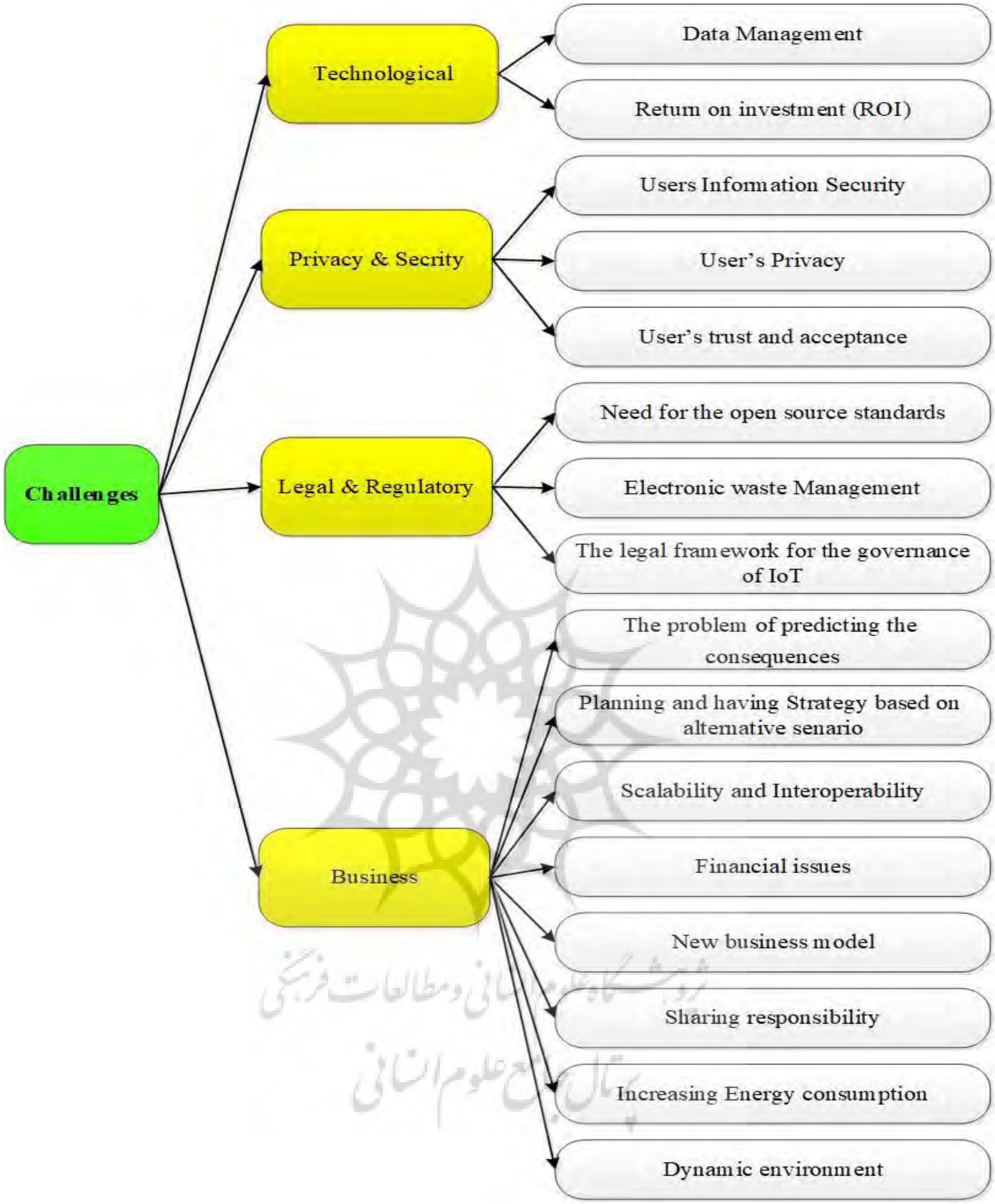

Figure 3. Criteria and codes of the category "Challenges"

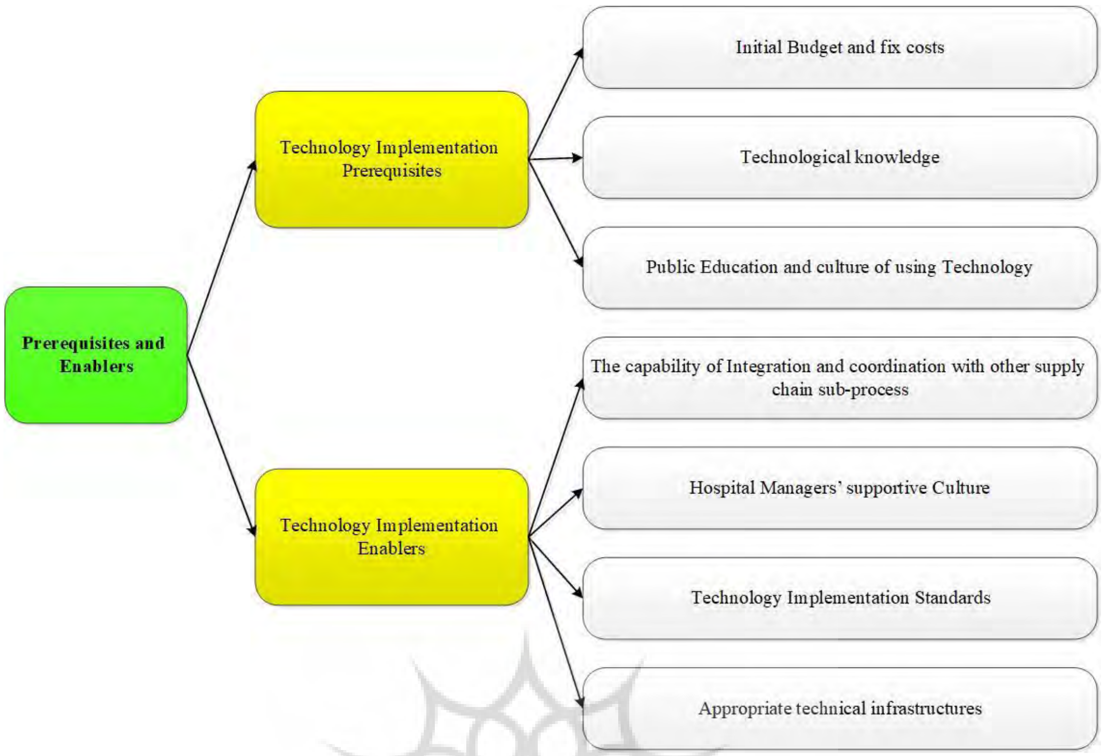

Figure 4. Criteria and Codes of the category "Prerequisites and Enablers"

Based on Figure 5, the. main7category of "Environmental and9Contextual. Conditions8of1the0 IoT Implementation in. hospital7supply chains" had two subcategories of0"General conditions" with two codes and the sub-category. of9"hospital and health industry conditions" with two codes.

Environmental and contextual characteristics are the special conditions that influence the underlying phenomena and strategies. These conditions generally affect the main phenomena at a large or specific scale of the hospital industry and usually have similar effects on all hospitals.

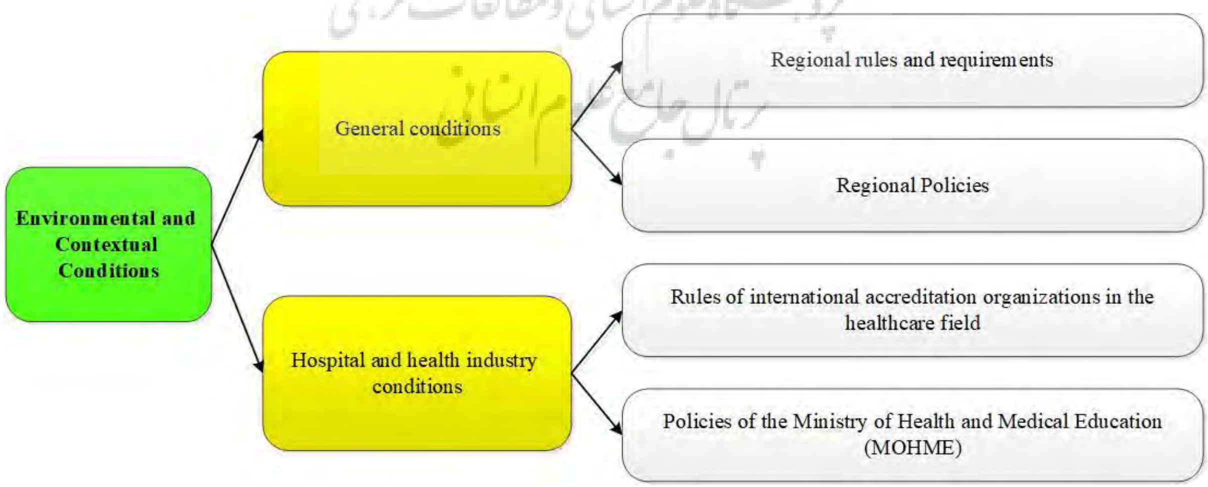

Figure 5. Criteria and Codes of the category "Environmental and Contextual Conditions"

According to Figure 6, the main category of "Strategies of the IoT Implementation in hospital supply chains" had three subcategories of "Public Policy-Related Strategies" with three codes, "Industry Supply Chain Strategies" with three codes, and "Hospital Strategies" with two codes.

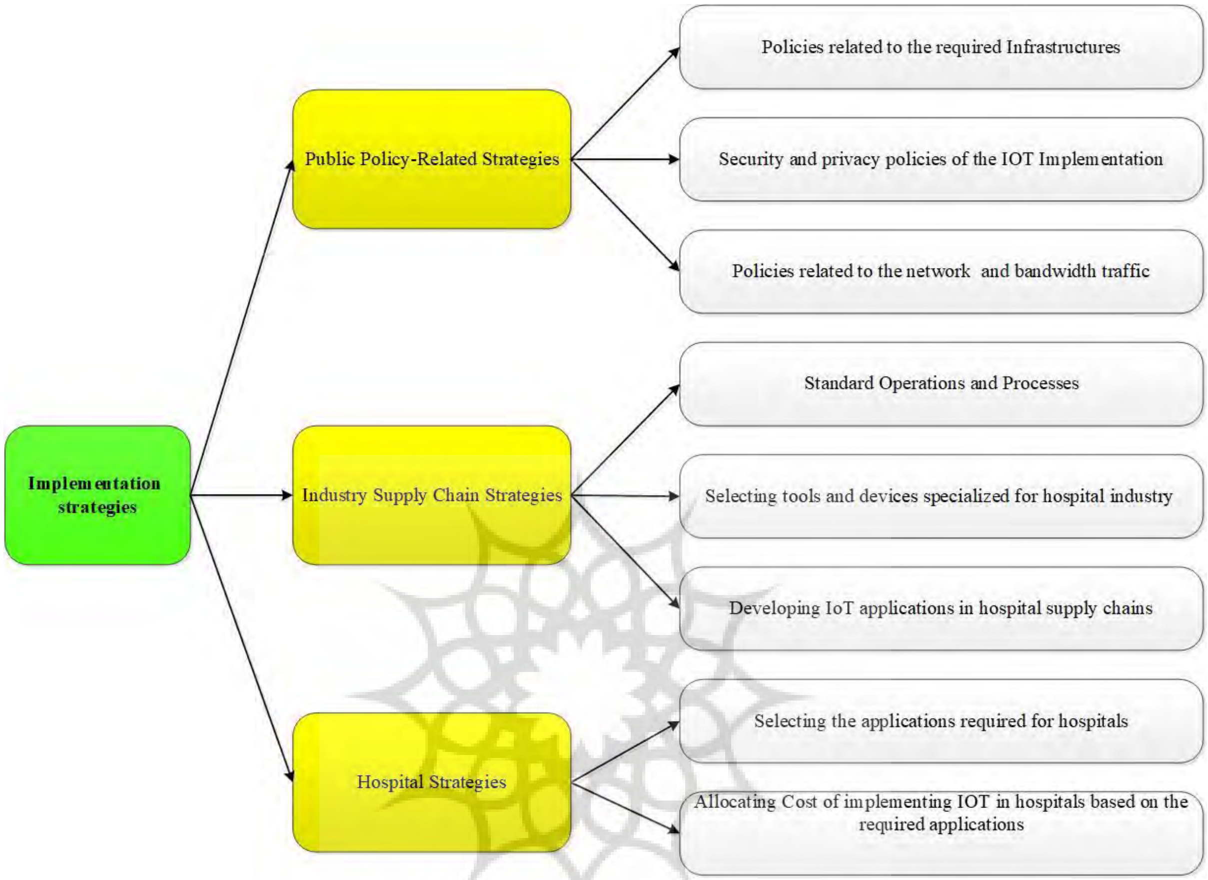

Figure 6. Criteria and Codes of the category "Implementation Strategies"

According to Figure 7, the main category of "Results and Outcomes of the IoT Implementation in hospital supply chains" had four subcategories of "Functional Outcomes" with thirteen codes, "Economical Outcomes" with eleven codes, "Social Outcomes" with eight codes and "Environmental Outcomes" with six codes.

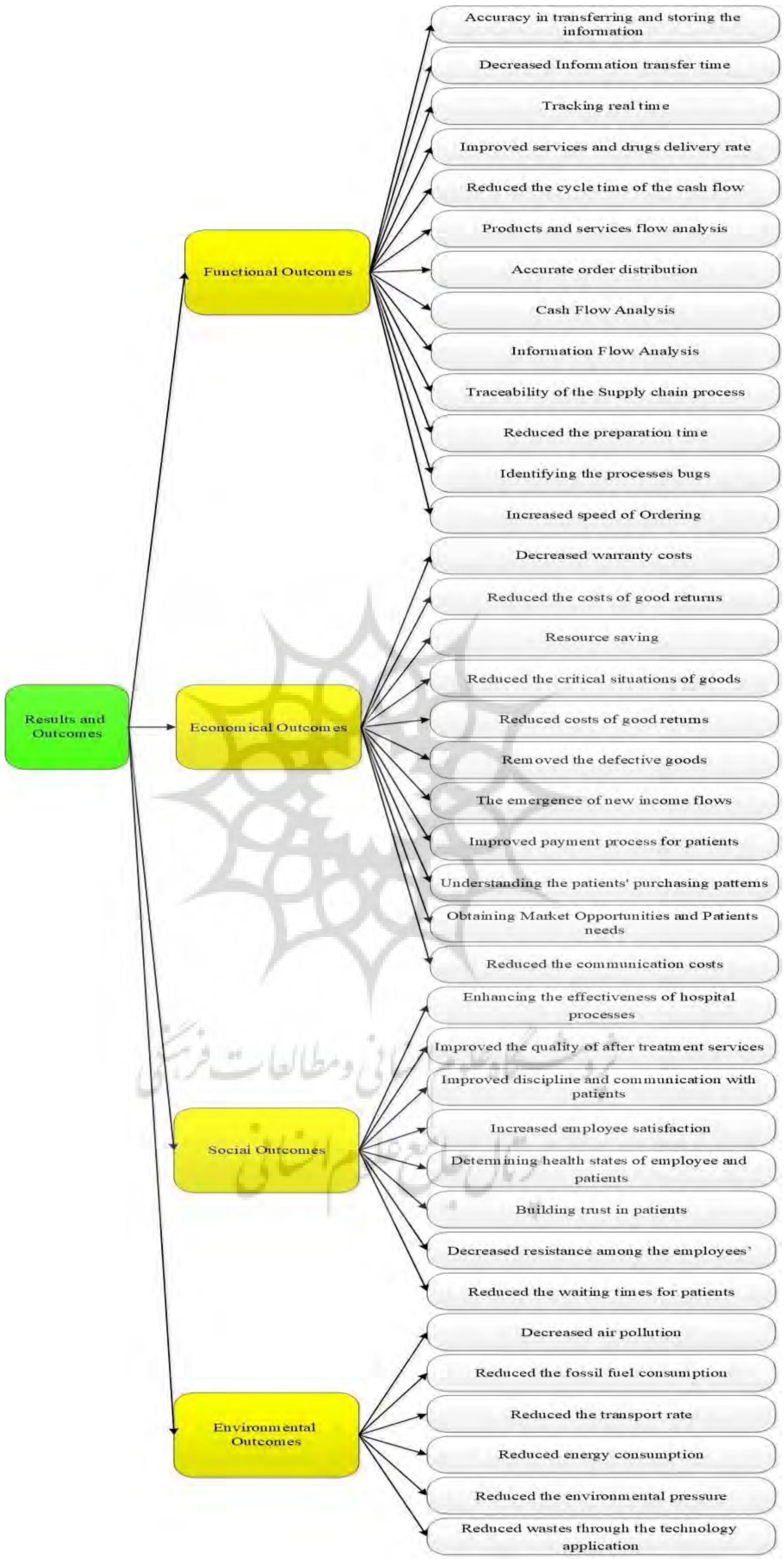

Figure 7. Criteria and Codes of the category "Results and Outcomes"

Based on Figure 8, finally, the category of "The Main Phenomenon of the IoT Implementation in hospital supply chains" had two subcategories of "IoT-based hospital supply chain" with three codes and "IoT technology implementation" with five codes.

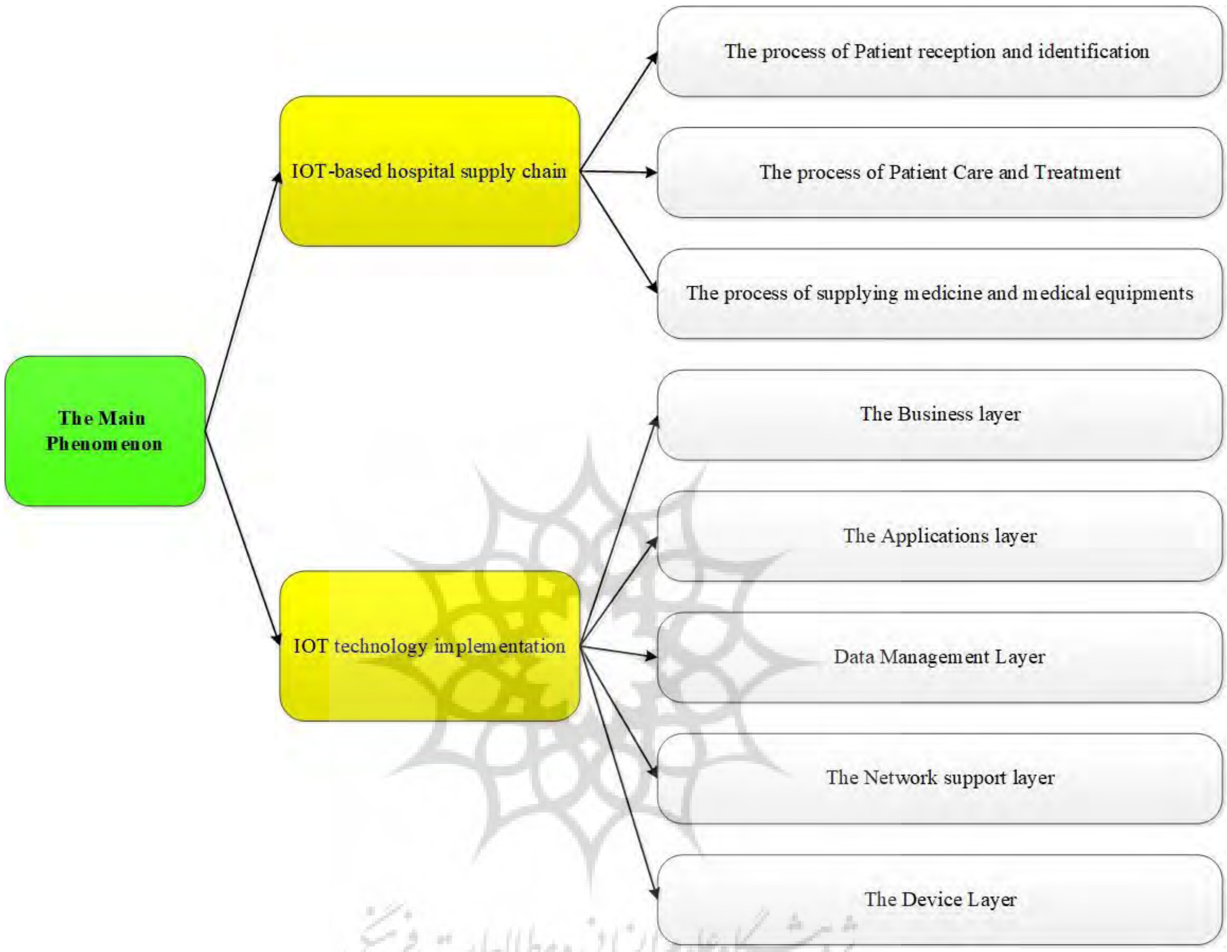

Figure 8. Criteria and Codes of the "Main Phenomenon"

As shown in Figure 9, the final model was derived as "Conceptual Modeling of the Internet of Things Implementation in Hospital Supply Chains".

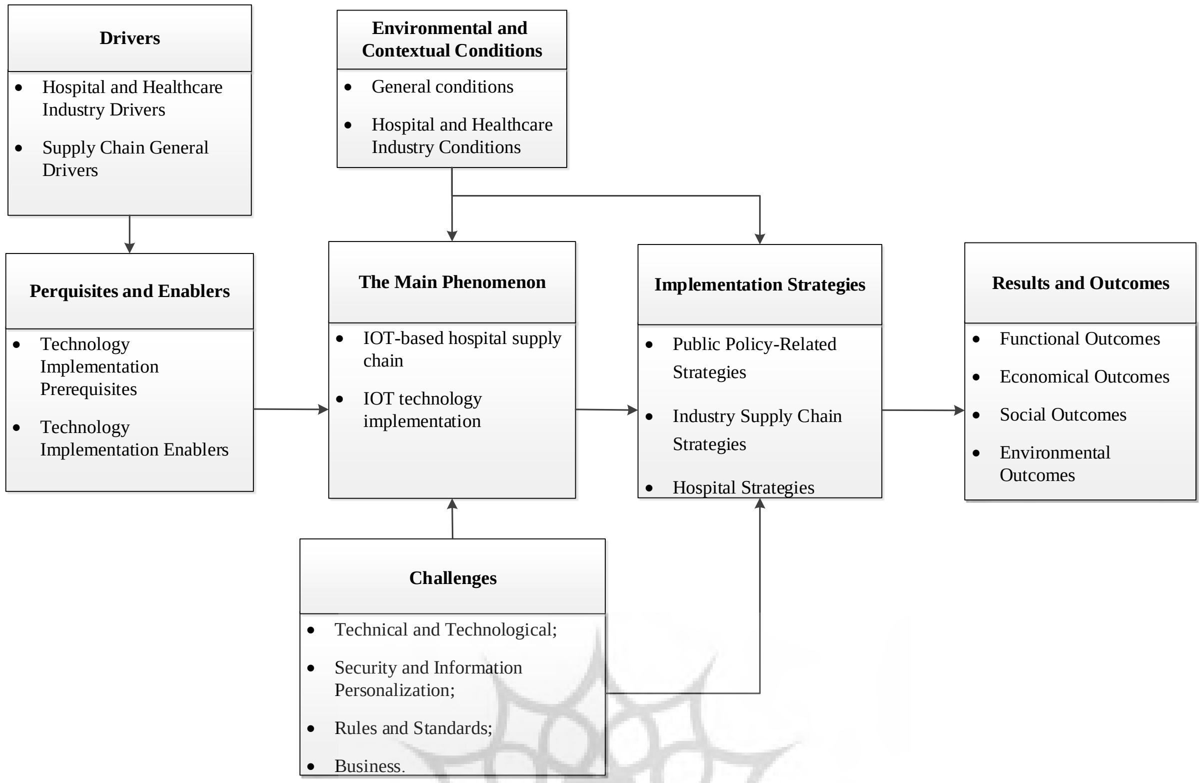

Figure 9. The Paradigm model of implementing IOT in hospital supply chains

Discussion

The purpose of this study has been to achieve the conceptual model of implementing the internet of things in hospital supply chains. The research was conducted through the library and field methods. In order to achieve the main objective of the research, the researcher followed two secondary objectives: 1. defining the fundamental concepts of the IoT implementation in hospital supply chains; 2. classifying the concepts into conceptual modeling and determining the relationships between model dimensions.

After identifying the relevant articles, the selected ones were extracted through the meta-synthesis method. Then the final model was extracted through deriving the consistent concepts by the methods including the grounded theory, open coding, axial and selective coding.

The research results indicated that the model featured seven main categories, 19 subcategories and 86 codes. The results also presented a conceptual model for IoT implementation in hospital supply chains including an explanation of the main research category, drivers, prerequisites and enablers, environmental and contextual conditions, challenges, technology implementation strategies, and results and outcomes.

In our model, the subcategories and codes were explained as well as the main categories (basic concepts), providing a great guide for implementing the IoT in hospital supply chains.

Moreover, the final model extracted can be useful for explaining the model of the IoT implementation in other supply chains and the related industries. In addition, unilateral or mutual relationships between the model's main categories act as good guides for successfully implementing the IoT based on the organizations' goals and balancing their available resources. Even in other research, these can be studied and analyzed as dynamic systems.

In the present study, the researcher has made every effort to exploit the most recent and most reliable sources as well as ensuring the research reliability and validity in several ways. The results of this study implied the effectiveness of using IoT technology in different industries thereby reducing risk, uncertainty, and costs. Given the direct communication of the hospital industry with human lives, these results were of greater necessity in the industry mentioned.

Conclusion

The research results indicated that the conceptual modeling of the Internet of Things implementation in hospital supply chains featured seven main categories, 19 subcategories, and 86 codes along with the relationships between the main categories. "The Main Phenomenon" of the model that is the Internet of Things implementation in hospital supply chains consisted of two subcategories including "IoT-based hospital supply chain" –involving the main hospital processes-and "IoT technology implementation" involving the layers constituting the IoT concept. Other categories and subcategories of the model include:

- "Drivers of the technology implementation" with two subcategories of "Hospital and Healthcare Industry Drivers" -having three codes- and "Supply Chain General Drivers" with two codes.
- "Prerequisites and Enablers" with two subcategories: "Technology Implementation Prerequisites" -with three codes - and the "Technology Implementation Enablers" subcategory with four codes.
- "Environmental and Contextual Conditions of the Technology Implementation" with two subcategories of "General conditions" with two codes and "Hospital and Healthcare Industry Conditions" with two codes.
- "Challenges of the Technology Implementation" with four subcategories including the "Technical and Technological Challenges" subcategory with two codes, the " Challenges of Privacy and Security" subcategory with three codes, the "Legal and Regulatory" subcategory with three codes and the "Business Challenges " subcategory with eight codes.

The conceptual model of implementing the Internet of Things in hospital supply chains had the categories of "Results and Outcomes" and "Implementation Strategies":

- "Implementation Strategies" with three subcategories of "Public Policy-Related Strategies" -with three codes-, "Industry Supply Chain Strategies" -with three codes and

"Hospital Strategies" with two codes were extracted.

- “Results and Outcomes of implementing the Internet of Things technology” with four subcategories of “Functional Outcomes” with thirteen codes, “Economical Outcomes” with eleven codes, “Social Outcomes” with eight codes and “Environmental Outcomes” with six codes.

Suggestions

From the results of the research, we can point the application of the IoT technology implementation model in hospitals, analysis of the results before and after the implementation of the IoT technology, and measuring supply chain performance indicators such as performance, sustainability, elasticity, etc. in the supply chain. The output of the model also explains all the dimensions needed to implement the IoT technology, which can greatly assist in the implementation of this technology and its results in practice. Finally, it is suggested that researchers explore the modeling of the IoT in other sectors of the health industry such as manufacturing and distribution of drugs, manufacturing of medical equipment, etc. In order to increase the generalizability of the research results, it is recommended to evaluate and assess the implementation of the IoT in the supply chain of public and private hospitals using case studies.

Conflict of interests

The most important limitation of the current study was the poor communication between the Iranian healthcare industry with the international market due to the sanctions imposed against Iran. In addition, the technological gap between Iran and other countries of the world as well as finding all the IoT experts, especially in hospital supply chains, may have influenced the research results. Therefore, it is suggested that researchers control the mentioned limitations and use our results as the basis for future research in this field. In general, the results of the present research enhanced our awareness of implementing the internet of things in hospitals. Based on the results, additionally, it is suggested that managers use our model to implement the IoT in hospital supply chains.

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