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Research Article

EVALUATION OF THE POTENTIAL OF THE INTERNET OF THINGS IN HEALTH SERVICES WITH MULTI CRITERIA DECISION-MAKING METHODS

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ABSTRACT

Background: With the technology developing all over the world, there is a transition period to the Industry 4.0 revolution in the field of health. The Internet of Things is one of the themes of Industry 4.0. Treatments applied in diseases have increased the use of health services with the increase in the world population. For this reason, there is a healthcare sector among the areas where the internet of things has turned into technology.
Objectives: The impact of the Internet of Things potential on healthcare organizations is especially based on the reliability of patients and other institutions accessibility and sensitivity. It is very important to establish a correct and timely diagnosis and to start the treatment process in health institutions. The most important unit that is effective in providing these treatment processes is operating rooms. In this process, the integration of devices with internet technology and use by healthcare professionals provides more effective follow-up of patients. Thus, it contributes to the treatment process. In this study, the internet transition of things in the health sector is examined.
Methods: In this study, the analytical network process method was used. ANP method was used because of the interaction and feedback between the criteria.
Results: The internet potential of things in health services was evaluated using the analytical network process method. The evaluation and the determining criteria are aimed to increase the efficiency of the operating rooms and hospitals.
Keywords: ANP, industry 4.0, internet of things, IoT potential, operating rooms.

1. INTRODUCTION

Industry 4.0 refers to the fourth industrial period as the term. Following the first and second industrial revolutions, the digital revolution, the third industrial era, has emerged. Industry 4.0 consists of cyber-physical systems, the Internet of things and the internet of services. By observing physical processes with cyber-physical systems, it is aimed to create a copy of the physical world and to make decentralized decisions. The internet of things and cyber-physical systems will be able to work in real time with each other and with people in cooperation [1].

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The industrial revolution by James Watt, which began with the invention of the modern coal engine by charcoal, was followed by the use of electricity and oil in mass production. In this way, the fourth industrial revolution was reached with the spread of the internet and the internet of things. The Internet of Things (IoT), which has been most frequently heard recently, first appeared in 1999. This system is used especially among the smart factories which are formed by the fourth industrial revolution. It is much easier to access instant data thanks to this technology, which enables the devices of the sectors to communicate with each other. After the communication between the devices themselves, detailed analysis and reporting are directed to the appropriate device. Thanks to this technology, production performance is maximized [1].

It is possible to define the Internet of things by communicating with each other by means of various communication tools and by connecting to each other, sharing information and forming a smart network [2]. The Internet of things s hould not only be perceived as connecting the devices to the Internet. Radio frequency identification (RFID), similar sensors and descriptors to produce information with some devices is also within this concept. When equipped with things, sensors and electronic circuits, it is able to communicate with people and gain the ability to update status information [3].

Together with the developing technology all over the world, there is also a transition period in the field of health to the Industry 4.0 revolution. Major changes in the field of science and technology, especially in the field of genetics and medicine, are emerging. Medical care and health services in the Internet of Things represent one of the most attractive areas of application. IoT applications and services affect our lives to a great extent.

The health benefits of IoT can be grouped into three categories:

(i) monitoring of things and people (health team, staff and patients),
(ii) identification and verification of people and
(iii) Automatic data collection and detection.

Chronic diseases, psychological problems, the number of patients with surgery and the number of people with various diseases increased the use of health services. However, the potential of IoT solutions for health problems and treatments in hospitals is taken into account. In 1999, Kevin Ashton used the Internet of Things for the first time in 1999 when he was making a presentation on the benefits of RFID technology from P&G [5].

Medical care and health services for the Internet of Things represent one of the most attractive areas of application [4]. In a comprehensive study conducted in this field, the advantages of the Internet of things in the field of health have been stated and attention was drawn to the solutions in the field of health [4].

Looking at other studies in the literature Ozkarahan et al. [6], in order to use the operating rooms more effectively, each operative time and the day of surgery. The inputs in the computer model include different methods to define the duration of the patient's operation, the hours kept for each day, and the number of cases allocated for each week. Van der Lans et al. [7] aimed to minimize the duration of the emergency operating room and to keep the operating room utilization at the highest level. Aktaş et al. [2] contributed to the literature by conducting studies on the internet-based data collection and analysis system of objects for biomedical applications.

In this study, multi-criteria decision making (MCDM) methods were used to examine the potential of IoT in healthcare. The criteria evaluated during the selection process were determined by the literature review. These criteria were evaluated using the Analytical Network Time (ANP) method. The ANP method used in the study is a process that takes into account the dependencies of the factors in the decision problem. Impact, addiction and feedback are the focus of ANP. Dependencies and feedback between factors are also taken into consideration, instead of linear structures in other classical approaches [8].

This study consists of four parts. In the second part, a literature search was made about the methods used and the ANP method which is one of the MCDM techniques used in the solution of

the study is mentioned. In the third part, the problem was solved by the ANP method. In the fourth part, evaluation and re sults are given.

2. MATERIAL AND METHODS

According to the reviews, literature studies on MCDM techniques in the field of health services are quite limited. Eren and Gür [9] performed an application on the evaluation of factors affecting the performance of operating rooms with fuzzy AHP. Gur et al. [10], have made observations on the determination of the criteria affecting the performance of the operating room in hospitals by analytical network process.

Under this heading, a general review of E-health applications related to the concept of the Internet of the object was made. The fields of application in the literature are examined and the studies on the current situation in the world are as follows: [4; 11-16]. Aksakal and Dağdeviren [25] applied the ANP method in the selection of personnel in their study. By developing an integrated model with the DEMATEL method, they applied the model in an industrial engineer recruitment decision for a factory and tried to identify the best candidate among the 4 candidates. Yazgan and Üstün [26] used the ANP method for pilot selection in their studies.

One of the biggest goals of the Industry 4.0 revolution is to develop a production process that takes advantage of feedback by making data analysis and responds to the needs in a very short time. It is also to enable product development processes with high automation and efficiency. Today, health systems have started to take shape with the concept of industry 4.0. The internet, which is currently being used, is widespread and it is desired to include the applications of all medical processes on virtual platforms. Health 4.0 concept has started to be used as the equivalent of industry 4.0 concept in health institutions. With Health 4.0, various applications were developed in the field of health and a great transformation process was initiated. When the studies in which the researchers examined the effects of industry 4.0 in the health sector, it is seen that various applications are made. With the introduction of the concept of industry 4.0 into the literature, the researchers first included component descriptions in their work plans. Then they discussed the applications of these components in the manufacturing or service industry. There are a limited number of studies on the concept of industry 4.0, which has just started to take a place in health systems. Looking at these studies in the field of E-Health; surveillance systems for the health status of elderly people in the hospital or home [17]; fall detection systems for elderly people or people with disabilities [18-22] medical coolers for organic elements, vaccines and medicines, athletic surveillance in high performance centers [23]; stimulating systems exposed to intense UV rays at certain hours can be given as examples.

Also; Manogaran et al. [27] proposed a secure Internet of Things architecture (IoT) to manage scalable sensor data for healthcare applications. Thuemmler and Bai [28] conducted a study to follow the developments in industry 4.0 and design principles in sensitive medicine. They conducted research on the rapidly advancing evolution of smart drugs in chronic, non-communicable diseases. Kılıç [29] aimed to identify the role of health services in Turkey and levels the application of industrial 4.0. He actively evaluated the applications used. Paulin [30] discussed data traffic in hospital and general health systems. He conducted researches to reveal the complex relationship regarding the access, storage, transmission and management of data in the field of health services. Elhoseny et al. [31] aims to increase the performance of health systems with its big data collection mechanism. They wanted to optimize cloud-IoT applications, a tool to efficiently manage large amounts of data generated by the introduction of Industry 4.0 into healthcare systems. Sharma and Tripathi [32]; Makkar et al. [33]; Thangaraj et al. [34] analyzed the challenges and opportunities faced by this revolution in the health sector. Sharma and Mahapatra [35]; Farahani et al. [36]; Qadri et al. [37] discussed the progress of the internet of things in the health sector. They analyzed the innovations of industry 4.0 for health services. When these studies are evaluated, it is seen that the concept of industry 4.0 has been in the world

literature for the last ten years, but the definition and conceptual framework of this concept has just started. The focus of this study is to evaluate the potential of health practices. There are limited studies in the literature that address health practices. In addition to this, the importance of this study in the literature highlights the importance of evaluating the potentials and including qualitative evaluations in the solution process.

The concept of industry 4.0, which has an extension in the health sector, is defined as an industrial revolution that relies on inter-unit communication, provides real-time access to all data obtained on the sector basis, and focuses on sustainability and technological development. Although it was born in the field of industry, its effect is seen in every sector today. If the technological products needed to be used in the health sector are taken into account, it will be inevitable for the hospitals to see the most reflected industry 4.0. The development of patient-specific devices that make digital transformation in health seem to be one of the important advantages of industry 4.0. The software and hardware developed enables the production of completely personalized products for patient needs by providing smart information exchange.

These innovations and developments, which are planned to be experienced in health branches, should be in a quality to support uninterrupted and efficient human-data-machine relationship. In the light of these developments and innovations, health services are in a continuous transformation. Following the transformation, health information systems are used to collect data about various processes in health institutions, to ensure the storage and security of this data. These health information systems cover not only the storage of data but also the decision support systems, medical terminologies and documentation processes of the units. In addition, by providing personal recording systems, individuals are provided with the opportunity to access their medical data and obtain information about their health status.

2.1. Analytical Network Process (ANP)

The analytical network process was developed by Thomas L. Saaty and is based on a double comparison. At the point of decision, many criteria and the relations between these criteria are easily modelled. In short, ANP ensures that relations between criteria and alternatives are taken into account in the decision-making process. It also provides a more efficient and realistic analysis of the problems by modelling the problem in a multifaceted way.

General ANP follows these steps:

Step 1. Determination of decision problem: The separation of the problem and the creation of the network structure is the first stage of the method.

Step 2. Determining the relationships between the criteria: In order to analyze a system, the number of criteria, sub-criteria and alternatives should be determined. At the same time, their interactions within the model should be considered.

Step 3. Making pairwise comparison matrices between factors: In order to determine the severity of the criteria and sub-criteria among themselves, pairwise comparison matrices should be formed.

Step 4. Consistency check of pairwise comparison matrices: It is necessary to check whether the decision maker is consistent in making comparisons between criteria. For this, there is a "consistency ratio" for each matrix. This consistency ratio of 0.10 or less is considered sufficient.

Step 5. Sequence generation of super matrices: The creation of an unweighted super matrix is the first step for the limit super matrix. Each matrix section in the structure shows the relationship between two factors within the system. In the second step, the weighted super matrix is generated. The last step is to obtain the limit super matrix. The force of the super matrix $(2k + 1)$ is taken to ensure that the weights are equalized at some point. Here k is a large number selected randomly and the resulting new matrix is called the limit super matrix.

Step 6. Finding the final weights and making the best choice: With the help of the limit super matrix, the importance weights are determined for alternatives or the factors being compared. The alternative, which has the highest importance in the selection problem, is the best alternative.

3. RESULTS

In this study, industry 4.0 and the effect of the concept of the Internet of Things on health systems and operating rooms were examined. The flow chart of the study is shown in Figure 1.

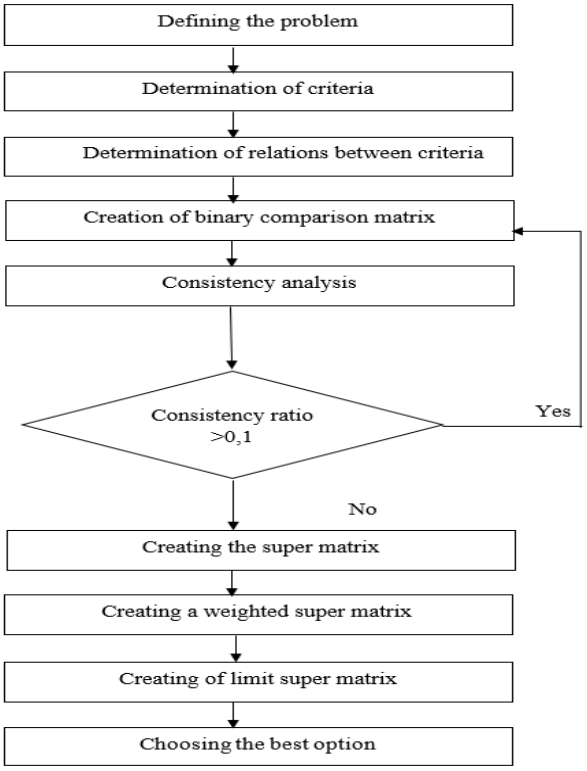

Figure 1. Flow chart

3.1. Evaluating the Potential of the Internet of Things in Healthcare Systems by Multi-Criteria Decision-Making Methods

Industry 4.0 is a collective term that includes many modern automation systems, data exchanges and production technologies. Considering the reflections of developing technology in the field of health, many innovations arising from the concept of industry 4.0 stand out. With the idea of Industry 4.0, digital health service started to be developed for individuals. These reflections in the health sector aim to accelerate progress and development in hospitals and to increase the quality of service provided to patients. The impact of these transformations in health systems on hospitals has become a subject open to research. It has become possible to examine the reflection of these innovations, which are experienced with the internet of things, on health systems, and may lead to different results for both healthcare professionals and patients. By

evaluating these effects, it will facilitate the advancement of technology on the health system. In this study, it is examined the effects of the internet of things which are the subjects of industry 4.0 and the applications in health field and its effect on operating rooms. In order to investigate the potential of IoT in health services, a process modelling was conducted to investigate its effects. For the purposes of this study, the convenience of the Internet of things in institutions, employees and patients is observed in health institutions. Important criteria related to health field have been determined as a result of consultation with experts on the subject and literature review.

3.2. Determination of Criteria

The industry 4.0 which was formed by the development of the industry within the periods; It is a combination of technology and organizations. In the study, the Internet of things and their applications in the field of health are discussed. The criteria used in the study were based on the study of Tsiounia [24] and a literature review was performed. As a result of the literature review, the criteria related to health field and especially operating rooms have been determined. These criteria are the most important features to be considered in the field of health. Criteria and explanations are given in Table 1.

Table 1. Determination of Criteria

Criteria and Definitions	
Concreteness	The IoT is based on the idea that objects store, process, and transmit information. For this reason, surgical equipment can be monitored, and the condition of any room can be checked.
Reliability	Hospital staff (staff, medical team, anaesthesiologist, surgical team) and patient can be followed up correctly and reliability can be ensured. Customized services, timely transactions and treatments can be provided by these actions. In addition, the lack of data in medical records is very important in the accuracy of the diagnosis. Personal medical data may prevent delays or errors in transmitting documents from a mobile app.
Sensitivity	Sensitivity refers to the sensitivity of the entire process. Industry 4.0 refers to the introduction of the cyber-physical system and it is of great importance for all studies to pay attention to this issue.
Application completion time	This is the time that elapsed during the registration of the patients.
Diagnostic accuracy	IoT can help to remove unnecessary tasks or to improve required and value-added tasks. The implementation of IoT potentially contributes to process performance and quality of health care. In addition, the patient's medical application procedure adversely affects the time of admission or diagnostic accuracy due to delay or false filling. In addition, the lack of data in medical records is very important in the accuracy of the diagnosis.
Accessibility	IoT plays an important role in the monitoring and verification of people. Therefore, it is very important to reach everything that is desired in the operating room.
Health data collection	Automatic data collection and detection is provided through the internet of things. In this way, the health data is collected in a comfortable way and is provided in operating rooms.
Necessary Equipment Inspection and Maintenance	Before the anaesthesia of the patient, special instruments, necessary medicines and materials, surgical instruments and materials are used to be used by the operating room nurse. The patient should not be treated before all materials are electronically entered and confirmed.
Ensuring Patient Information Security	The safety of patient information is important in electronic environment. For this reason, the hospital staff can access their information electronically in order to provide security.

3.3. Solution of problem with ANP

Based on the opinions of the experts and the studies in the literature, pairwise comparisons were made between the criteria. These comparisons were analysed by ANP method from MCDM methods. The relationships and interactions between the criteria are shown in Figure 2.

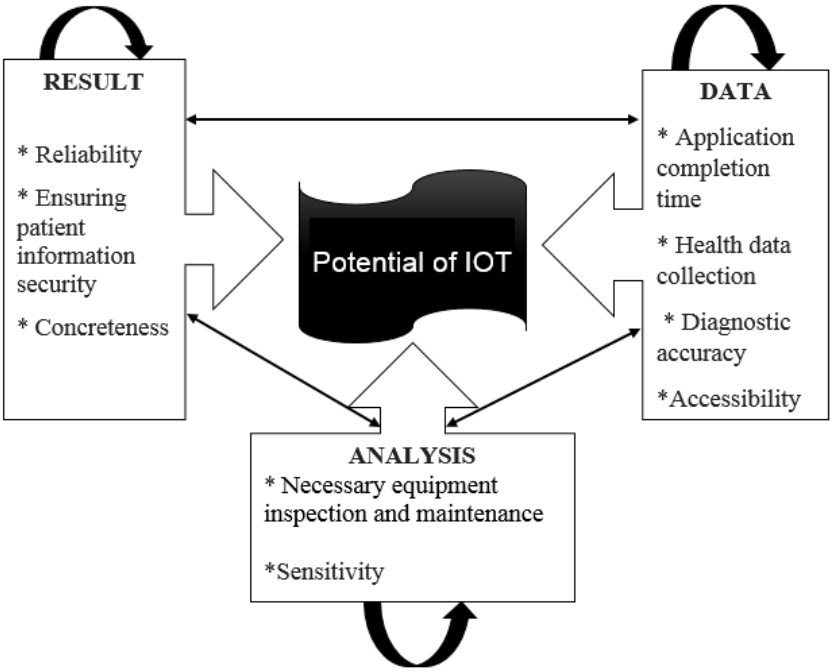

Figure 2. Network structure showing the relationship between criteria

IoT potential in health services is of great importance. In this context, a literature review has been made and important criteria have been determined considering the opinions of the experts. These criteria are linked to each other and analysed.

In the ANP method, after the network structure created due to the interaction between the criteria, pairwise comparison matrix structures are established. These matrices are created among the criteria that are related to each other. During the evaluation, 1-9 scale of Saaty is used. A similar matrix structure is shown in Table 2. Among other criteria such as this matrix structure, the matrix is created according to their interactions with each other.

Table 2. pairwise comparison matrix between criteria

Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Health data collection
Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Diagnostic accuracy
Health data collection	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Diagnostic accuracy

Criteria are examined in 3 groups. Groups are results, data and analysis. These groups are formed by combining similar criteria. In order to determine the severity (weight) of the criteria, the relationships between each other are taken into consideration according to the network structure given in Figure 2. The resulting weights are shown in Table 3.

Table 3. Final weights calculated for evaluation criteria

Name	Criteria Weights
Reliability	0,39165
Ensuring patient information security	0,21497
Concreteness	0,39338
Application completion time	0,05198
Diagnostic accuracy	0,52456
Accessibility	0,2046
Health data collection	0,21885
Necessary equipment inspection and maintenance	0,22198
Sensitivity	0,77802

With the exchange of information, jobs in health services become easier. With the internet of things, healthcare personnel and patients can handle their work more quickly and on time (Internet Source)[2]. Security, accessibility and concreteness are very important in health services. Patient and hospital equipment should be traceable, and condition should be controllable. In this way, both patient and hospital data are collected easily. At the same time, the data related to the patient can be processed and monitored in intelligent machines. The traceability of the health data of the patients helps easy diagnosis and diagnostic accuracy. In addition, health data is collected in a short period of time and remote patient follow-up is in keeping with the era of health. Thanks to intelligent machines, the duration of the patient's application and the processing times are accelerating. When performing these procedures, care is taken to ensure patient information security. Thus, the reliability of health organizations is increasing one more. It is very important to provide easy access to patient information or inter-institutional information as well as being reliable in an institution. Accessibility starts from the recording of the patient or objects. All the information in patients should be reached and the correct diagnosis and correct result should be easily reached. If the access is late, the diagnosis and diagnosis are delayed. In this way, the health of the patient may be delayed. As a result of correct diagnoses, surgery is sometimes performed. Here, the IoT potential comes into play and helps our health workers. The patient's past knowledge, diagnosis and results are easily reduced, and the likelihood of error making is greatly reduced. This situation increases the reliability of the health institution. The traceability of the patients' conditions provides great convenience in all areas at any time. The patient is provided with accessibility to the equipment within the condition of being operated. The complete and clean equipment ensures the correct and regular operation. In health facilities, cleaning and maintenance of operating rooms are taken into consideration in consideration of human health. Regular maintenance is recorded in electronic media. These records are monitored and controlled continuously. In this way, both the patient health and the reliability of the health institution will increase. These criteria are intended to increase the efficiency of the operating rooms. Because operating rooms are shown as the most important unit of hospitals.

4. DISCUSSION AND CONCLUSIONS

In the process of transition to the fourth industrial revolution, the health sector also has a 4.0 revolution. Health organizations with this industrial revolution have become a special situation, for example, space limitation has been removed, where it can be delivered to anywhere, the latest

technology, the person is able to offer customized diagnosis and treatment. In this process, the IoT potential, which is closely related to the fourth industrial revolution, is discussed. However, its effect on the operating room units in the hospital is examined. With the effect of IoT potential, many conveniences are provided in hospitals. These facilities greatly affect personnel, patients and institutions.

When we look at the applications of Industry 4.0 on health and intended to exist, all this should be perceived as a radically new system, a new cycle, rather than a change. It should be seen as a continuous transformation in terms of quality, efficiency, cost and similar factors. The success rates and possible risks of such great innovations should be strategically evaluated. This transformation in the health sector should cover not only cyber physical structures but also qualified manpower. The infrastructure of the systems should be strengthened by making use of people's experiences and insights. In other words, the human factor should be added to this great transformation.

With the introduction of the fourth industrial revolution into our lives, there are major changes in science and technology, especially in the field of health. With Industry 4.0, physical dependence on health institutions was abolished, and the service provided could be delivered anywhere, any hour. Projects have been developed to bring innovations that offer personalized facilities and treatments with the latest technology.

With these new technologies developed and envisaged, individuals become more conscious about their own health. It is planned to increase productivity and efficiency with these conscious individuals who also grow in the field of health. At the same time, these technologies also have significant resource savings and cost advantages. In traditional methods, a lot of time, money and effort was spent developing treatment for a disease. With the revolution of Health 4.0, big data analysis can be done more easily and quickly. With these data analyzes, it is possible to examine many cases.

There are many decision-making problems solved under MCDM. There are many solution techniques for these problems. In this study, one of these techniques, the ANP method is used. In this study, the problem of evaluating the potential of the IoT in health services is discussed. The criteria were determined by specific experts and by literature review. In this study, we determined the criteria for evaluating the potential of IoT in health services and weights were obtained by ANP method. However, the literature was reviewed, and the criteria were collected in 3 groups. Groups are results, data and analysis. These groups were formed by associating similar criteria. As a result of this, the sensitivity and importance given to health institutions and operating rooms are mentioned.

It is important to bring the service provided in health institutions to the most appropriate point. This increased reliability in hospitals. Necessary information should be obtained by considering patient information security to ensure reliability in health facilities. Gathering information in a short time is also a way of achieving diagnostic accuracy. In this way, the treatment process is accelerating. One of the most sensitive units in health facilities is the operating rooms. Therefore, accurate health data should be collected in a short time. As a result of the collected health data, the equipment to be used must be complete and regular maintenance is required. In this way, solutions can be provided with the conveniences provided by the Internet of the things against the problems occurring during the operation. Thanks to the Internet of things, patient records are easily made and the information is transported to the future, and even after a few years, all information about the patient, employee and institution can be easily accessed. In this way, diagnosis and treatment will be provided in a timely and accurate manner. This study may contribute to all investigations in the field of health. Based on this, different criteria and different methods can be applied. In the literature, the researchers can take the example of this study and, in later times, study in fuzzy situations.

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Competing interests

The authors declare that they have no competing interests.

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Ethics approval and consent to participate

This study does not require ethical approval.

KEY POINTS

- The importance of industry 4.0 and its applications on public health policy and practice
- Impact of the Internet of Things potential on health institutions
- Impact of Industry 4.0 on health
- Health 4.0 and public health innovations
- Health 4.0 applications in hospitals and the factors affecting the applications

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