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Exploring opportunities and challenges of Blockchain-Based Electronic Medical records

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Abstract

Available research suggests using Blockchain in electronic medical files to aggregate and integrate information. While reviewing authoritative articles and books, we analyzed the challenges and opportunities of using Blockchain this way. By using the specialists' opinion, completing a specialist questionnaire, using the DEMETEL technique and interpretive structural modeling (ISM) technique, this research investigated and analyzed the possibilities of using Blockchain in electronic medical files. The pair comparison technique was used to study and analyze the challenges of using Blockchain this way. The results are stated in this research. Research achievements include the design of a model using Blockchain for electronic medical files, analysis of Block chain's opportunities and challenges, measurement of the components, design and presentation of the model, and prioritizing the challenges of using Blockchain. This research suggests that the use of Blockchain in electronic medical files can reduce extra costs, create a comprehensive system for medical records to avoid additional costs, facilitate access to patient information, and reduce medical errors. The results obtained reveal that the components of immutability and the impossibility of data forgery of patient

records (based on data integration in Blockchain) have the most impact on the system. Examination of the challenges reveals that blockchain technology's challenges (low speed, difficulty working with Blockchain, poor integrations between the software for various electronic health records) are of the utmost importance.

Keywords: Blockchain - Electronic Medical Records - DEMATEL - Interpretative Structural Modeling -Pair Comparison

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Introduction

"Health care data management has been gaining a lot of attention in recent years because of its high potential to provide more accurate and cost-efficient patient care" (Ismail et al., 2019). Due to the disintegration and diversity of systems, it is impossible to analyze and process data obtained from medical-related records quickly. Blockchain provides the possibility of instant access to the results of medical research and medical innovations. In this respect, Blockchain provides a significant potential development in the world of healthcare. Generally, once health records are loaded into the system, they remain unchanged. Blockchain could be used to facilitate the sharing of such data (Chen, 2019). One of the crucial issues in the field of treatment that receives much attention today is the technology and digital tools to provide more efficient medical services (Forbes Weekly, 2019). Blockchain is well-known for its applications in the finance, supply chain, and banking sectors (Bamakan et al., 2021). However, Blockchain decentralized and distributed technology can be utilized as a powerful tool for daily life applications (Kumar et al., 2018).

Healthcare is a field that will potentially have significant effects on blockchain usage. However, researchers and specialists in informatics and health care are still at the research and development stage (Jeet & Singh kang, 2020). Traditional patient visits are very time-consuming and costly; applicants for different treatments face many challenges. Lack of aggregation of an individual's medical information makes it necessary for people to bring their medical records, medical documents, test results, etc., for each visit to a medical center. Sometimes, rework occurs, and due to insufficient information from the doctor about the patient's medical records, medical errors occur, leading to human casualties and even death. Lack of aggregation of an individual's medical information results in much damage, human, financial, temporal, etc., which is sometimes irreparable. Reducing and creating a comprehensive system for medical records will save additional costs, prevent illegal access, facilitate legal access to patient information, and reduce medical errors. Our goals for this research include examining the opportunities and challenges of blockchain use for electronic medical files, exploring the opportunities and challenges of using blockchain technology, and providing practical solutions for the use of Blockchain this way. The disintegrated nature of the healthcare supply chain and rising costs create several challenges. The healthcare industry needs effective solutions that can streamline supply chain operations and processes in a cost-effective manner (Reda et al., -2020). Several problems in healthcare stem from the complex network and the lack of traceability of transactions. Blockchain has the potential to solve these problems as it provides trust without any intermediaries, has traceability as a default feature, and promises new business models by enabling novel structures. Blockchain has gathered significant potential in the healthcare industry (katuwal et al., 2018). The use of blockchain technology in healthcare is remarkable and has a considerable impact on the healthcare industry (Hussien et al., 2021)

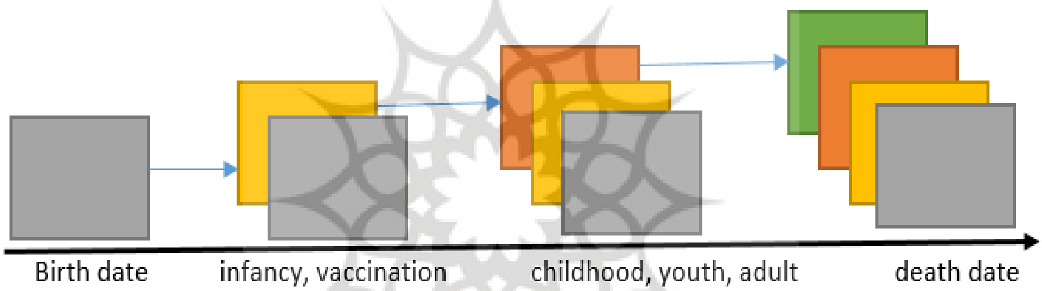

Figure 1. The life cycle of a human being from a blockchain perspective (Pandey & Litoriya, 2020)

Using technology for medical care in the form of electronic registration of medical data and electronic health systems is one of the essential issues for improving health care quality. The healthcare ecosystem has new opportunities and challenges ahead of the comprehensive application of information and communication technology in medical affairs. Electronic healthcare express to be the next big wave in the healthcare industry, which makes security the essential component in this framework (maseleno et al., 2020). Electronic health files are a collection of patient digital health information in electronic form. This can improve the quality and cost of health care, and as a result, it is being adopted by many developing countries (Sahney and Sharma, 2018). Electronic health records provide new opportunities and a chance to rethink the creation of health processes and thus improve the quality of health (World Health Organization, 2004). Health is one of the basic human needs, and the provision of high-quality, safe, effective, and as affordable as possible health services are one of the main tasks of governments. Electronics cities are rapidly developing, and electronic health is one of the most critical applications there. The necessity for an electronic health record, which can be easily accessed by the patient and their physician in the general surgery and secondary care wards, has been acknowledged for about a generation and is evident to everyone.

However, a small number of countries around the world have efficient national systems in this field. Accurate and complete preservation of records is an essential part of the management of patient treatment. Paper medical records are a part of the information management problem because they are illegible, inconsistent, and a significant obstacle for anyone who wants to know about a patient's outcome. Paper used as a means of recording health data in most medical centers and organizations has led to extensive follow-up in the field of writing, and most organizations are interested in changing paper-based health records to electronic records. Implementation of electronic health records requires preparation but can still cause problems (Hertzum and Ellingson, 2019).

Improving and upgrading this system to a dynamic, up-to-date, secure, and fast system in which the flow of information meets systemic needs, in addition to an improvement of the quality of health services to the community, will be the basis for considerable savings in a country's medical costs. The use of electronic health records in improving people's health will be statistically significant (yeung, 2019). Using an electronic health file, physicians can increase efficiency by reducing unnecessary administrative requirements. Providing better quality medical care will ultimately lead to progress in the patient recovery process because an electronic health file will include the patient's profile, medical history, test results, radiographs ... With an electronic file, access to the above information will be very easy for the doctor and the patient without any time constraints. The most active electronic health countries primarily include Canada, the United States, and the United Kingdom, and secondly, Austria, Cuba, Finland, France, Germany, Italy, and China. The most discussed topics on the electronic health front that have led to investment and planning include electronic health and telemedicine records, training and disease monitoring systems, clinical information systems, and information exchange standards. Achieving the electronic Health goals depends on using modern information and communication technologies to securely and efficiently collect and needs electronic health records and make them accessible to authorized users and healthcare providers (sookhak et al.,2021). Blockchain is one of the innovations in the recent decade. Many applications already notoriously hard and complex are fortunate to facilitate the service with the blessings of blockchain and smart contracts. (Hewa et al.,2021)

Blockchain in medical records

Blockchain is made up of the two words "block" and "chain." This technology involves a connected chain of blocks (Akhavan et al., 2018). In general, Blockchain is a type of information recording and reporting system (Philsoophian et al., 2021). Its difference with other systems is that the information stored on this system is shared among all network members. As it uses cryptography, it is almost impossible to delete and manipulate the recorded information. Healthcare is an area that is supposed to have effective impacts on the Blockchain) jeet & Singh Kang, 2020). Applying blockchain technology to the healthcare industry could improve information security management; healthcare information could be analyzed and expressed while preserving the privacy and security of the data. (Farouk et al., 2020) The data replication, transparency, immutability, security, and privacy features of Blockchain have a novel future in the healthcare domain (Ismail et al., 2020). Any information can be recorded in any Blockchain block: from a person's medical record to accounting information for assets such as bitcoin. Blockchain and information technology related to it will revolutionize our health care system. We believe that it will provide a much more efficient and fluid environment with improved performance. (Abu Jamra and Randall, 2019) in the health care sector. Health generally requires approval, the ability for cooperation, and the requirement of sharing recorded data due to legal requirements, such as the law of Accountability and reliable health insurance, which are blockchain applications. (MC, 2019) .The Blockchain revolution has opened its way to the healthcare industry, which is the beginning of unique future events. The results of a survey by IBM called (Rally of Health and Wellness) shows that 16 percent of executives in companies and healthcare organizations have serious and consistent plans to launch Blockchain-based business services. That figure is anticipated to rise to 56 percent by 2020. Although blockchain use will improve the performance of healthcare systems, it may also face us with challenges.

Table 1. The four main challenges in the field of healthcare affected by Blockchain Technologies (zhang et al. -2018)

Challenge	**Meaning**
Scalability	data recorded on the Blockchain should be checked
Storage	Storage space should be minimized while providing access to data
Privacy	Data transparency and keep secrets of patient in Blockchain must be considered
Evolution	Although Blockchain is immutable, it must support the evolution of health systems

In 2020, Pandey & litoriya noted the following gaps as a result of a literature review for medical records based on Blockchain:

We found a gap in the literature while systematically discussing the threats and challenges when national health care policy is implemented on a large scale. Most of the reviewed research articles reflected theoretical strategies in using technology in health care and other areas. Even though the practical aspects and challenges of using it were not discussed, blockchain technology was presented as simplifying the health care business. However, the increasing role of Blockchain in the health insurance sector has received very little attention. Blockchain has shown great potential in transforming the conventional health care industry. However, several research and operational challenges hinder the full integration of blockchain technology with existing medical record systems. The literature shows that blockchain technology is still relatively immature in healthcare, especially in the health insurance sector. However, blockchain technology research and its application in healthcare data management are growing. Based on the Review of articles revealing that Blockchain has tremendous potential in health care, other innovative and more efficient methods for its use in life insurance and health insurance can be researched. These opportunities should be used to manage electronic health records to increase the accuracy and security of medical records. Decentralized blockchain technology can be used to support access control, medication, pregnancy, or any management of data relating to severe illness, clinical trials, counterfeit drugs, and audit rejection control for health-related activities. Blockchain provides a secure and transparent integrated health care system that enables patients to stay in the center. It allows the efficient implementation of health insurance programs throughout the country. According to the literature review, the benefits and opportunities for medical records based on the Blockchain can be considered.

Table 2. An overview of the opportunities of using Blockchain in medical records

source	Advantages
Pandey & litoriya -2020 Farouk et al -2020	Privacy, security
Dagher et al -2018 Chen et al -2019	Security and Secure access
Hylock & Zen – 2019 Dagher et al - 2018	Safe and interactive environment
Tanwar et al- 2019	Improve data accessibility
Esmaeilzadeh & Mirzaei - 2019	Health care development
Cyran.M. A - 2018	Data protection
Jiang et al -2018 Sater -2018	Exchange of information
shi et al-2020	Telemedicine
Siyal et al -2019 Ismail et al – 2020 Hussien et al - 2021	Advances in the current medical industry
Kumar et al - 2018	decentralized

Methodology

The literature review revealed the opportunities and challenges of using Blockchain for electronic medical files. The final components were compiled by interviews with experts and are described below. A quantitative method was then used, including the DEMATEL method (Decision making trial and evaluation laboratory) to measure the relationships between the concepts in the model and achieve a network structure between the components. The ISM method was used to level the network structure obtained from the DEMATEL technique, which is described in detail below. It was necessary to measure the intensity of interactions between the existing components in the mentioned model using the DEMATEL technique. The layers were then leveled using ISM, an interpretive structure method.

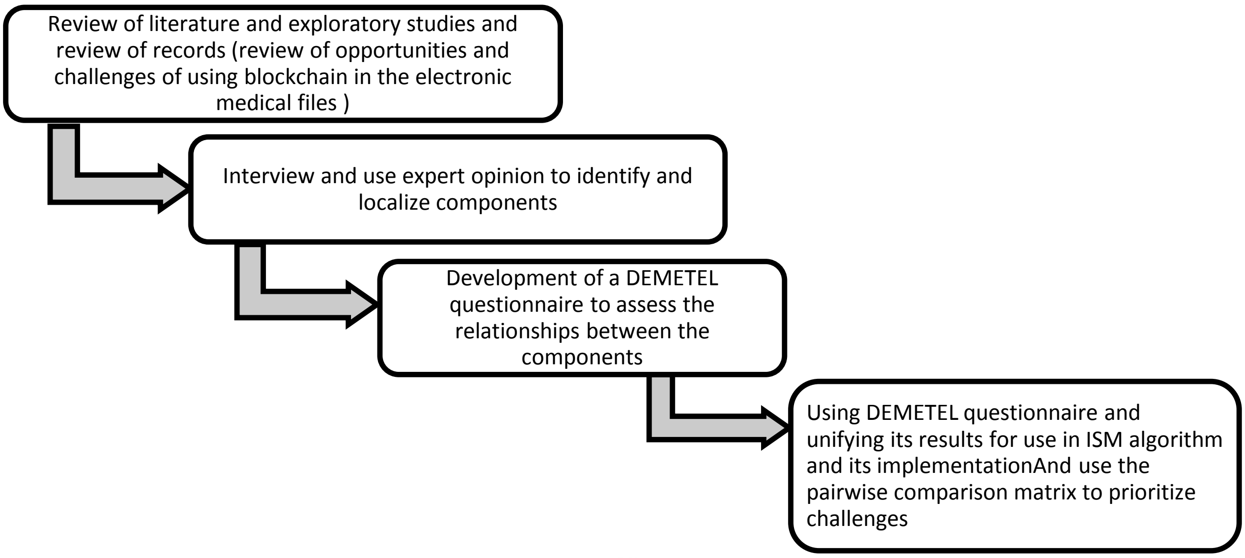

Figure 2. The research structure

To review and prioritize the challenges of using Blockchain in electronic medical files, we intend to prioritize the challenges using a pairwise comparison matrix. In order to identify and measure the intensity of cause-and-effect relationships between the components of the model obtained in this study, the phase-wise DEMATEL technique was used. The DEMATEL technique is a decision-making technique based on multiple criteria. It is a comprehensive method for analyzing and creating a structured model based on cause and effect relationships in problems with many components. Fontella and Gabus first proposed this method in 1978. In order to implement this method, the following steps must be performed:

• Step 1: Select experts in the field of research.

• Step 2: Specify the criteria and components of research and determine the language scale for them.

• Step 3: Calculate and collect Expert Evaluations. Expert members are asked to perform a set of matrices according to defined linguistic terms.

• Step 4: Calculate the direct communication matrix. In this step, we formed the direct communication matrix using the initial DEMATEL matrix. If there are several respondents, we can create a matrix using the arithmetic mean method of comments.

In this step, the DEMATEL decision matrix was completed using the table3.

Table 3. Relations between language idioms and values

-No impact	0
Very little impact	1
Low impact	2
High impact	3
Very high impact	4

• Step 5: Calculate the normal direct communication matrix. In this step, we normalized the direct communication matrix from Step 1. For normalization, the relation N = K * M is used. In this formula, K is calculated as follows.

$$K=\frac{1}{\max \sum_{j=1}^{n} a_{ij}} \tag{1}$$

• Step 6: Calculate the Complete Communication Matrix. The total communication matrix was calculated from the relation T = N × (I-N) -1. In this relation, I is a unique matrix.

• Step 7: The factor's impact and influence can be calculated using R and D factors. We calculated the sum of the row and column of the complete correlation matrix (T).

• Step 8: Draw a cause-and-effect diagram, or Cartesian coordinates, of the components from Step 7. We calculated the sum of the row and column elements of the complete relation matrix (T). The sum of each line's elements (D) for each factor indicates the impact rate of that factor on other factors of the system. The sum of the column elements (R) for each factor indicates the impact rate of that factor on other aspects of the system. The horizontal side of the figure4 shows D + R, and the vertical side shows D-R.

The ISM method for interpretive structures was used to level the network structure obtained from the DEMATEL technique. This method first identifies the effective and primary factors, and then by analyzing the criteria, analyzes the relationship between indicators at several different levels. In general, the main advantages of this method are its ability to understand a wide range of people, integrate the different opinions of experts, and study complex and diverse systems.

• Step 1: Formation of self-interactive structural matrix. In this step, the experts consider the criteria in pairs and respond to the pairwise comparisons.

• Step 2: In this step, the effects of the dominant relationships upon the relationship of the components are determined.

• Step 3: The law of group decision. In this step, elements A and B determine a collective agreement on the existing relationship for each pair.

• Step 4: The ISM technique is based on the "transferability of relationships," and expert judgments should be based on this factor. At this stage, the matrix is adjacent to the diagram.

• Step 5: The access matrix is calculated from the existing proximity matrix. Access to station j is possible from the assumed station i from a diagram. In terms of Direct (i → j), from the path of two arcs, three arcs, or a route with a maximum of n-1 arcs.

One of the possible strategies for calculating different routes from i to j is access to the matrix T. The calculations of this matrix are performed using the "Boolean" operation, and the access to the matrix T is calculated from the following equation:

$$T = (I + D)^{n-1} \quad ; t_{ij} = \begin{cases} 1: & \text{If there is a path from i to j , with a maximum arc (n-1)} \\ 0: & \text{Otherwise} \end{cases} \tag{2}$$

• Step 6: In this step, the complete relational matrix () is separated. In this research, a partition of a structure has been used to separate the matrix surfaces from the possible surfaces. To divide into these levels, we have

$$L_j = \left\{ N_i \in \left[N - L_0 - L_1 - L_2 - \ldots - L_{j-1} \right] / R_j(N_i) = R_j(N_i) \cap A_j(N_i) \right\} \tag{3}$$

• Last Step: In this Step, the diagram obtained from the results of the division of the previous step is drawn.

$$\begin{cases} R_j(N_i): & \text{.All vertices whose columns have an input of 1 in i row} \\ A_j(N_i): & \text{.All vertices whose rows have an input of 1 in i=j row} \end{cases} \tag{4}$$

In this research, the average of opinions has been used; for this purpose, a cut was considered K = 0.77 according to the value of the desired cut threshold. For all values greater than or equal to this section, the obtained complete relational matrix elements are considered equal to one and for all lesser values equal to zero. Thus the direct relational matrix of the entire relational matrix (Direct and indirect communication) is obtained. Due to the use of the results of the DEMATEL technique, the implementation of the interpretive structural modeling technique continues in this way. In order to examine and prioritize the challenges of using Blockchain in electronic medical files, the pair comparison method is used, which is as follows. They should all be compared in pairs. We also pair the sub-criteria within each category based on the main criteria.

This comparison is based on the range of nine-degrees Saaty (1997):

Table 4. The range of nine-degrees (Saaty, 1977)

Value	Comparison status of i with j	Explanation
۱	Equally preferred	Elements i and j are of equal importance
۳	Moderately preferred	The element i is slightly more important than j
۵	Strongly preferred	The element i is more important than j
۷	Very strongly preferred	The element i is much more important than j
۹	Extremely preferred	The element i is totaly more important than j
۸-۶-۴-۲	Intermediate	Intermediate values

Results

Using the literature review and validation questionnaire, the components of blockchain application opportunities in the Electronic medical files were reviewed by experts, and the following components were approved. Before starting to run the DEMATEL algorithm, the components were named according to the table below for ease of operation.

Table 5. Excluding the benefits and opportunities of using Blockchain in the electronic medical records file

Name	Opportunities and benefits
C1	Blockchain-based patient records (trust - convenience - quick recovery - quick access - simultaneous access - accuracy - reliability --....)
C2	Medical research (improvement of the research process - threatening diseases - epidemic diseases - reduction of recurrence - correction of medical deviations and treatment --....)
C3	Supply Chain Management
C4	Ability to participate and interact with information based on Blockchain (Medical Care - Information --....)
C5	Reduce fraud and errors (Pharmaceutical - insurance -Hsabdary -...)
C6	Transparency (invoices - files -...)
C7	Save time and money (booklet cost -..........)
C8	increase efficiency and productivity (accurate decision-making - desirable services -....)
C9	Data integration in Blockchain
C10	Blockchain-based data protection and security
C11	Immutability and impossibility of data forgery

The research's statistical population was ten people, such as university professors, administrators, and research experts. They have completed a questionnaire survey. According to the steps mentioned for the DEMATEL technique, due to the fact that there were several respondents, we converted the questionnaires into a single matrix. We normalized it, taking into account the arithmetic mean.

Table 6. Normalized Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	0	0/102	0/079	0/092	0/112	0/092	0/119	0/106	0/102	0/083	0/086
C2	0/092	0	0/059	0/073	0/076	0/083	0/076	0/099	0/076	0/069	0/079
C3	0/066	0/059	0	0/073	0/086	0/086	0/099	0/096	0/092	0/079	0/083
C4	0/089	0/079	0/083	0	0/083	0/076	0/083	0/089	0/102	0/083	0/089
C5	0/086	0/069	0/079	0/089	0	0/083	0/102	0/102	0/092	0/099	0/102
C6	0/083	0/089	0/092	0/079	0/106	0	0/102	0/099	0/096	0/092	0/102
C7	0/096	0/089	0/102	0/086	0/096	0/092	0	0/112	0/069	0/066	0/063
C8	0/069	0/092	0/089	0/079	0/089	0/092	0/116	0	0/073	0/069	0/086
C9	0/096	0/096	0/092	0/092	0/096	0/099	0/083	0/089	0	0/092	0/109
C10	0/079	0/089	0/086	0/089	0/096	0/102	0/086	0/083	0/089	0	0/109
C11	0/092	0/106	0/096	0/092	0/119	0/116	0/086	0/092	0/096	0/106	0

With the help of the obtained standard matrix, we formed the complete communication matrix, which is as follows.

It should be noted that in the questionnaire, the direct relationships between the components were questioned, so in order to achieve indirect relationships, the sixth step of the DEMATEL algorithm was used. The sum of rows and columns is calculated for each row and column of this matrix. The highest row sum indicates the order of the elements that strongly influence the other elements. The highest column sum indicates the order of the elements under the influence. They will represent the hierarchy of elements under the influence. The sum of rows and columns are shown in the following tables, respectively.

Table 7. complete relations matrix

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**
C1	0/723	0/834	0/805	0/805	0/909	0/864	0/911	0/912	0/844	0/790	0/847
C2	0/677	0/608	0/657	0/658	0/733	0/715	0/731	0/760	0/687	0/651	0/703
C3	0/680	0/690	0/626	0/683	0/770	0/745	0/778	0/785	0/726	0/684	0/733
C4	0/725	0/733	0/728	0/641	0/795	0/765	0/792	0/808	0/762	0/712	0/766
C5	0/757	0/761	0/761	0/758	0/758	0/808	0/848	0/859	0/790	0/761	0/814
C6	0/778	0/801	0/795	0/772	0/880	0/757	0/873	0/883	0/817	0/779	0/839
C7	0/737	0/747	0/751	0/726	0/814	0/785	0/724	0/836	0/741	0/704	0/750
C8	0/705	0/740	0/730	0/710	0/797	0/774	0/816	0/723	0/732	0/697	0/758
C9	0/792	0/810	0/798	0/787	0/876	0/851	0/860	0/878	0/733	0/782	0/848
C10	0/754	0/779	0/768	0/759	0/848	0/827	0/835	0/844	0/789	0/673	0/822
C11	0/826	0/856	0/838	0/824	0/936	0/904	0/904	0/923	0/859	0/830	0/789

Table 8. total line values

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**
9/248	7/585	7/905	8/232	8/679	8/979	8/321	8/189	9/019	8/703	9/493

Table 9. total column values

C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**
8/159	8/363	8/263	8/128	9/120	8/800	9/077	9/217	8/484	8/069	8/672

From the table of line sums, it can be concluded that C11 (immutability and impossibility of data falsification) are the components with the most influence in the model, followed by C1 and C9 (block records based on Blockchain) and (integration of data in Blockchain), respectively. The next component is the one that has the most influence on the system or pattern. Also, from the total column table, it can be concluded that C8 (increase in efficiency and productivity) is the most strongly influenced component. From the eighth step, the sum and difference of rows and columns for each row and column of the matrix of complete relations are calculated; That the sum of rows and columns is equal to D + R, and their difference is also equal to DR and D + R indicates the effect of the desired factor in the pattern or system, and the larger it is, suggests that the factor. The view has more interaction with other System factors and is of great importance, and DR shows the power of influence of each factor. The values of D + R and D-R are as follows.

Table 10. Calculate the sum and difference of rows and columns

	D	R	D+R	D-R
C1	9/248	8/159	17/407	1/089
C2	7/585	8/363	15/948	-0/778
C3	7/905	8/263	16/168	-0/358
C4	8/232	8/128	16/36	0/104
C5	8/679	9/12	17/799	-0/441
C6	8/979	8/8	17/779	0/179
C7	8/321	9/077	17/398	-0/756
C8	8/189	9/217	17/406	-1/028
C9	9/019	8/484	17/503	0/535
C10	8/703	8/069	16/772	0/634
C11	9/493	8/672	18/165	0/821

In Cartesian coordinates, the position of each component (Ci) is determined by a point with coordinates (D-R and D + R) in the device. Thus a graphic diagram of the relationships between the components is created. The following figure shows the cause-and-effect relationships between the components

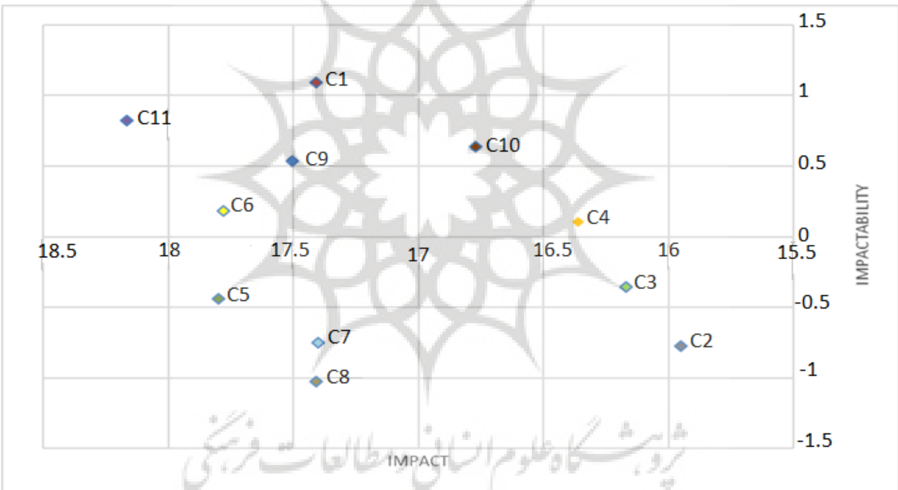

Figure guideline					
C1	Blockchain-based patient records	C2	Medical research	C3	Service supply chain management
C4	Ability to participate and interact with information	C5	Reduce violations and errors	C6	Transparency
C7	Save time and money	C8	Increase efficiency and productivity	C9	Data integration in Blockchain
C10	Blockchain based data protection and security		C11	Immutability and impossibility of data forgery	

Figure 3. Diagram of cause and effect relationships between components

According to the chart of cause and effect relationships between the components, it can be said that components C2, C3, C5, C7, C8 are among the components of effective and components C1, C4, C6, C9, C10, C11 are also among the components of cause. And among the components, C8 is the most effective component, and C1 is the most causal component.

Table 11. Classification of cause and effect components

variable	Component	Effect component	Cause component
C1	Blockchain-based patient records		✓
C6	Transparency		✓
C9	Data integration in Blockchain		✓
C4	Ability to participate and interact with information		✓
C10	Blockchain-based data protection and security		✓
C11	Immutability and impossibility of data forgery		✓
C2	Medical research	✓	
C3	Supply Chain Management	✓	-
C5	Reduce violations and errors	✓	
C7	Save time and money	✓	
C8	Increase efficiency and productivity	✓	

In order to avoid reprocessing and to achieve a direct communication matrix in the structural interpretive modeling technique, the average views have been used in this research. A cut is used to do this. And the desired section was considered K = 0.77. For all values greater than or equal to this section, the matrix elements of the obtained complete relations are considered equal to one and for all values less than equal to zero. And thus, the direct relationship matrix is obtained from the entire relationship matrix.

Table 12. Direct relations matrix of interpretive structural modeling

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C**	**C10**	**C11**
C1	0	1	1	1	1	1	1	1	1	1	1
C2	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	1	0	1	1	0	0	0
C4	0	0	0	0	1	0	1	1	0	0	0
C5	0	0	0	0	0	1	1	1	1	0	1
C6	1	1	1	1	1	0	1	1	1	1	1
C7	0	0	0	0	1	1	0	1	0	0	0
C8	0	0	0	0	1	1	1	0	0	0	0
C9	1	1	1	1	1	1	1	1	0	1	1
C10	0	0	0	0	1	1	1	1	1	0	1
C11	1	1	1	1	1	1	1	1	1	1	0

DEMATEL's complete communication matrix was used to obtain a direct communication matrix between the components, which was used as the input matrix of the interpretive structural modeling technique. Due to the use of the results of the DEMATEL technique, the implementation of the interpretive structural modeling technique of the fifth step is continued. Using Boolean algebra and the relationships described, the complete correlation matrix between the structural interpretive modeling technique components is calculated as follows.

Table 13. Complete relations matrix of interpretive structural model

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	1	1	1	1	1	1	1	1	1	1	1
C2	0	1	0	0	0	0	0	0	0	0	0
C3	0	0	1	0	1	0	1	1	0	0	0
C4	0	0	0	1	1	0	1	1	0	0	0
C5	0	0	0	0	1	1	1	1	1	0	1
C6	1	1	1	1	1	1	1	1	1	1	1
C7	0	0	0	0	1	1	1	1	0	0	0
C8	0	0	0	0	1	1	1	1	0	0	0
C9	1	1	1	1	1	1	1	1	1	1	1
C10	0	0	0	0	1	1	1	1	1	1	1
C11	1	1	1	1	1	1	1	1	1	1	1

Here we can perform Mick Mac analysis using the complete relational model of interpretive structural modeling. Mick Mac analysis is one of the topics of structural-interpretive modeling. Based on the power of dependence and the influence of variables, a coordinate system can be defined and divided into four equal parts. Mick Mac analysis is based on the influence (influence), and the degree of dependence (influence) of each variable and allows further study of the range of each variable. The penetration power indicates the number of elements that the i-th element affects and the degree of dependence of the number of elements that affect the i-th element. In Mick Mac analysis, variables are divided into four groups: autonomous, dependent, interconnected, and independent. Autonomous variables have little dependence and conductivity. These criteria are generally separated from the system because they have poor connections to the system. A change in these variables does not cause a severe change in the system. Dependent variables have strong dependence and poor conductivity. These variables generally have a high impact and little impact on the system. Independent variables have low dependence and high conductivity; in other words, high impact and low impact are the characteristics of these variables. Interface or link variables have high dependence and high conductivity; in other words, the effectiveness of these criteria is very high, and any small change on these variables causes fundamental changes in the system.

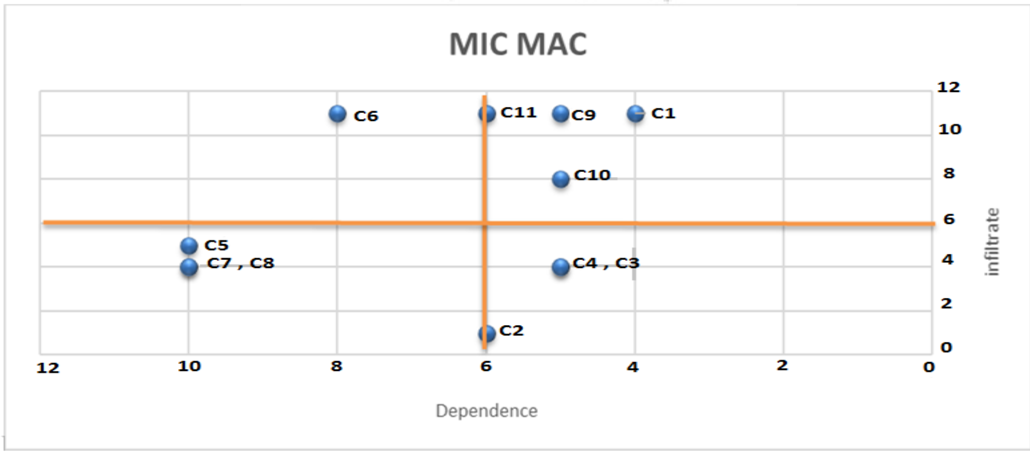

Figure guideline					
C1	Blockchain-based patient records	C2	Medical research	C3	Service supply chain management
C4	Ability to participate and interact with information	C5	Reduce violations and errors	C6	Transparency
C7	Save time and money	C8	Increase efficiency and productivity	C9	Data integration in Blockchain
C10	Blockchain-based data protection and security		C11	Immutability and impossibility of data forgery	

Figure 4. Mick Mac Analysis Chart

Components C2, C3, C4 are autonomous components. They have low dependence and conductivity. These criteria are generally separated from the system because they have weak connections to the system. A change in these variables does not cause a severe change in the system. Therefore, components C5, C7, and C8 are in the dependents group, which means they have strong dependence and low conductivity. Both have high dependence and high conductivity; in other words, this criterion's effectiveness is very high, and any small change on this variable causes fundamental changes in the system. Components C1, C9, C10, C11 are in the independent group. Independent variables have low dependence and high conductivity. In other words, high impact and low impact are the characteristics of these variables. In the continuation of the process, Step six is used to separate the matrix and determine the levels of network structure resulting from the output of the DEMATEL. All vertices whose columns have one input in row I and all vertices whose rows have input one in row i. The share of these two sets is calculated. If this share is equal to the set, then the component is graded, and after a complete repetition for all components, it is removed from the components in the next iteration. This process continues until all the components are leveled. The table below shows the first iteration, and its output shows the components at level one.

Table 14. The first iteration of the interpretive structural method leveling

Component	**Ri**	**Di**	**Di□Ri**	**First level component**
C1	C1……C11	C1,C6,C9,C11	C1,C6,C9,C11	-
C2	C2	C1,C2,C6,C9,C10,C11	C2	C2
C3	C3,C5,C7,C8	C1,C3,C5,C8,C11	C3	C3
C4	C5,C7,C8,C4	C1,C6,C9,C4,C11	C4	C4
C5	C4….C8,C11	C1,C3,……..C11	C5…..C9,C11	-
C6	C1…..C11	C1,C4…..C8,C9...C11	C1,C4, C5…C11	-
C7	C5……C8	C1,C3….C11	C5….C8	-
C8	C5……C8	C1,C3….C11	C5……C8	-
C9	C1………C11	C1,C5,C6,C8,C10,C11	C1,C5,C6,C8,C10,C11	-
C10	C2,C5……C9,C10,C11	C1,C6,C9,C10,C11	C9,C10,C11	-
C11	C1…….C11	C1,C5,C6,C9,C10,C11	C1,C5,C6,C9,C10,C11	-

It is observed that components C4, C3, C2 are at level 1. The second iteration continues with the remaining components by deleting these components, and its output also shows the second-level components. The process ends with the fourth iteration. In the seventh step of the diagram, the results of the separations of the previous steps are drawn. It should be noted that the network structure of the components (output of the DEMATEL technique) and their leveling (output of structural interpretive modeling) are all shown in the following diagram. The interpretive structural modeling technique's levels are appearing in the severity of the components' effectiveness, respectively, meaning that the first level represents the most effective level and the last level shows the most causal level. Here is the fourth level that offers the most causal level.

On the other hand, with the help of the results obtained from reviewing the literature and questionnaires of experts, the challenges of using Blockchain in the file of electronic treatment services were categorized as follows:

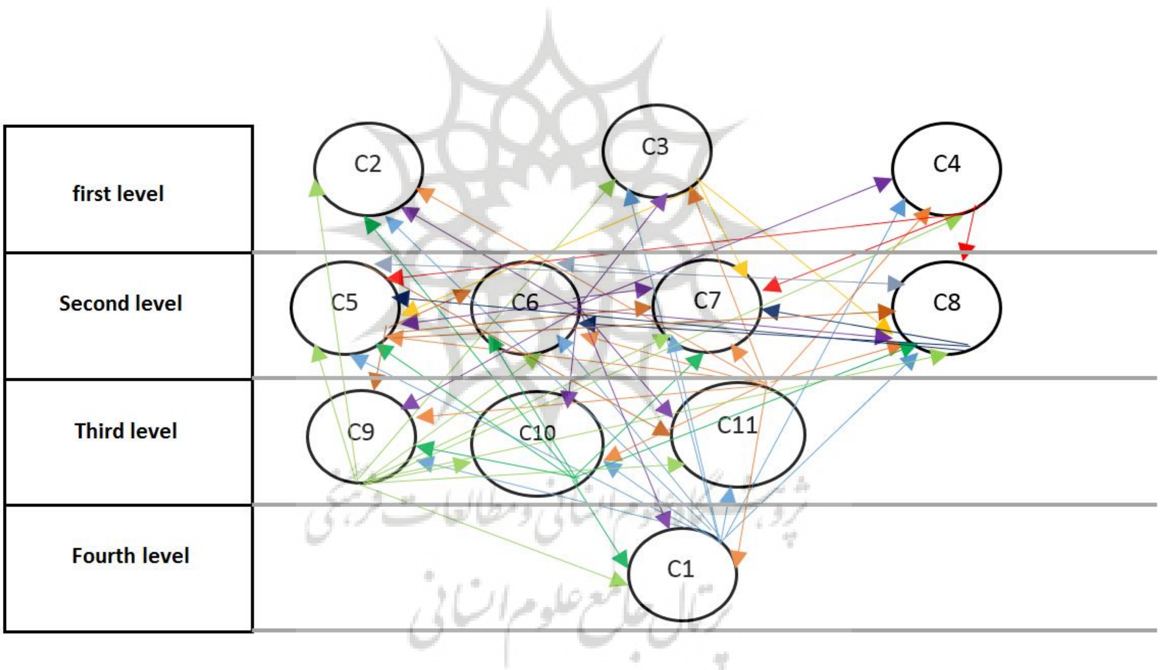

Figure Guideline					
C1	Blockchain-based patient records	C2	Medical research	C3	Service supply chain management
C4	Ability to participate and interact with information	C5	Reduce violations and errors	C6	Transparency
C7	Save time and money	C8	Increase efficiency and productivity	C9	Data integration in Blockchain
C10	Blockchain based data protection and security		C11		Immutability and impossibility of data forgery

Figure 5. The output of the Demetel method and the interpretive structural method in an image

Table 15. Challenges and limitations of using Blockchain in electronic medical files

Category title	Challenges
Human	Patient's unfamiliarity with cyberspace and Blockchain technology
	Insufficient information to the patient
	The patient's unwillingness to use virtual files for personal reasons
	Lack of familiarity of the treatment staff with blockchain technology
	Failure to complete the file by the doctor (failure to update the prescription and prescription)
	Attitudes of individuals
Process	readiness Limitations of organizational change created by Blockchain (lack of hospitals
	Cost constraints and high cost of blockchain technology
Technology	Low blockchain speed (low transaction per second)
	Difficulty working with Blockchain
	Poor interaction between electronic health record software

Using Expert choice software, we examined experts' opinions on the importance of the dimensions of the challenges of using Blockchain in the file of electronic treatment services, and the following result was obtained.

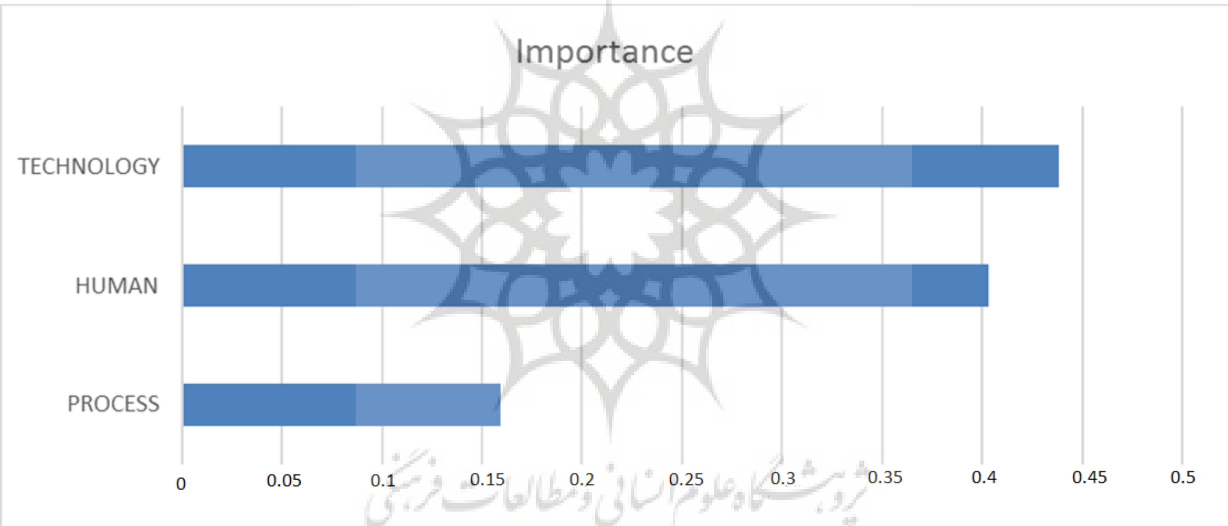

Figure 6. The importance of the challenges of using Blockchain in the electronic medical files

Table 16. Ranking factors based on Infiltration

	D
C11	9.493
C1	9.248
C9	9.019
C6	8.979
C10	8.703
C5	8.679
C7	8.321
C4	8.232
C8	8.189
C3	7.905
C2	7.585

According to the figure above, the components were ranked based on the importance of technology, humans, and processes. The most critical challenges are related to the technology dimension, and it is the most important. The human dimension is in the second place, and the process dimension is in the third place. Components of each dimension in order are: Technology (low blockchain speed (low transaction per second), difficulty working with Blockchain, poor interaction between electronic health record software) - human (patient unfamiliarity with cyberspace and blockchain technology, inadequate patient information, patient reluctance Using virtual files for personal reasons, the unfamiliarity of the treatment staff with blockchain technology, incomplete file by the doctor (failure to update prescriptions and prescriptions), attitude attitudes of individuals) - process (limitations of organizational changes created by Blockchain (Hospital unpreparedness -......), cost constraints and high cost of blockchain technology) are expressed.

Discussion

In this step, the results and outputs of the DEMATEL technique are analyzed and interpreted. The largest sum of rows (D) indicates the order of the elements that strongly influence the other elements. Therefore, the order of the elements in the row represents the hierarchy of the penetrating elements. According to the table16, the three components that have the most impact are components C11, C1, and C9, which are the immutability components (the impossibility of data forgery), blockchain-based patient records, and data integration in Blockchain. These are the reasons for choosing Blockchain for medical records. These components are significant because most medical data remains unchanged once it is loaded into the system.

The second most influential component in the model is the component of patient records based on the Blockchain that guarantees trust, convenience, fast recovery, fast access, quick simultaneous access, accuracy, reliability, etc., to the system. The third most influential component in the model is a blockchain-based data integration component because medical history is significant for diagnostic and treatment purposes. As a result, integrating blockchain-based medical data can be a great help to medical decisions and research. Also, the most significant sum of columns indicates that the order of the elements is affected. Therefore, the order of the elements from the column will represent the hierarchy of the elements being influenced.

Table 17. Ranking of factors based on permeability

	R
C8	9.217
C5	9.120
C7	9.077
C6	8.800
C11	8.672
C9	8.484
C2	8.363
C3	8.263
C1	8.159
C4	8.128
C10	8.069

According to the table17, the three most influential components are C8, C5, and C7. These components increase efficiency and productivity, reduce violations and errors, and save time and money. The first component, the one with the most permeability, relates to increasing efficiency and productivity. It can be said, perhaps, that this is one of the main reasons for using Blockchain.

The second component with high permeability relates to reducing errors and violations. When medical data is stored in a transparent and integrated blockchain-based method, mistakes and violations will decrease. These violations can include insurance and accounting violations. Many medical errors are also reduced too. The third component with high permeability relates to saving time and cost. This component is one of the main reasons for research because the existing system in health services is time-consuming and costly. It imposes a lot of costs on the current system and people and wastes people's time.

The ISM technique has divided the components into four levels based on the intensity of the cause-and-effect relationship. The first level includes medical research, supply chain management, the capability of participation, and data interaction based on Blockchain. The second level comprises reducing violations and errors, transparency, saving time and money, and increasing efficiency and productivity. The third level includes data integration components in Blockchain, blockchain-based data protection and security, immutability, and the impossibility of data forgery. The fourth level comprises the component of patient records based on Blockchain (trust, convenience, quick recovery, quick access, simultaneous access, accuracy, reliability, etc.)

Table 18. Description of levels of interpretive structural modeling

Level number	Level title	Components at the level
1	achievement	Medical research Supply Chain Management Ability to participate and interact with information
2	Process (improvement)	Reduce violations and errors Transparency Save time and money Increase efficiency and productivity
3	Technology	Data integration in Blockchain Blockchain-based data protection and security Immutability and impossibility of data forgery
4	Human	Blockchain-based patient records (trust, convenience, quick recovery, quick access, concurrent access, accuracy, reliability, etc.)

We examined and prioritized the challenges of using Blockchain in electronic medical services files through the pairwise comparison method. The highest priority challenges related to the blockchain technology itself (its low speed, the difficulty in working with Blockchain, and poor integration between electronic health record software). Then there were human shortcomings: a lack of patient and medical professional familiarity with cyberspace and blockchain technology, insufficient patient information, patient unwillingness to use virtual files for personal reasons, incomplete physician records, and attitudinal limitations. Additionally, there were challenges relating to the process, including restrictions on organizational changes caused by Blockchain, cost constraints, and the high cost of blockchain technology.

Conclusion

Considering the importance of the health care field and society's growing need to develop services in this area, the research conducted in this area is limited. Even less attention has been paid to the practical aspects and challenges involved in basing medical records electronically on a blockchain. In this research, we tried to examine the challenges and opportunities of using Blockchain in electronic medical files to evaluate the issue from different angles and prioritize the components to design a suitable model for the research topic. In this research, an attempt has been made to provide a framework for applying the Blockchain to medical files, as shown in Figure 5.

Our research has some other limitations as well. Data collection could be improved in future investigations. This article participants were experts working in healthcare, but future studies could gather data from corporations that have deployed Blockchain technology in their institutions. The collected data in such an approach might yield new insights about both healthcare and blockchain technology. Furthermore, other research methodologies, including case studies, could be applied for data collection and analysis, providing more depth to the research outcomes. The other limitation of this paper is the very early stage of blockchain technology.

Research achievements include: designing the dimensions and components of the opportunities and challenges of the model of using Blockchain in medical files, measuring the relationships between components, designing and presenting a pattern of opportunities to use Blockchain in medical files, and prioritizing the challenges of using Blockchain this way.

Future suggestions for research include investigation of the characteristics and contents of medical records, investigation of blocks in the Blockchain; design of a specific currency code in the healthcare chain and use a specific currency code in the healthcare chain to facilitate financial transfers, and finally, Review of the model's implementation and assessment of its success in achieving its goal.

In addition, future works must address some blockchain-related technical issues in healthcare, such as security, scalability, and decentralization topic. More research studies also need to address the embedding of Blockchain in healthcare practices. Conceptualization is an essential subject for a better understanding of blockchain experiments, especially in healthcare efforts. Future research should also concentrate on blockchain developments in health issues.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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