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Overcoming IoT Implementation Challenges in the Saudi Healthcare Supply Chain: An Integrated ISM-MICMAC Analysis

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Abstract

The Internet of Things (IoT) has the potential to revolutionize the healthcare supply chain in Saudi Arabia, offering a wide range of benefits, including improved patient care, reduced costs, and more efficient operations. However, the adoption of IoT in the Saudi Arabian healthcare supply chain is still in its early stages, and there are a number of barriers that need to be addressed. This paper identifies and analyzes 14 potential barriers to IoT adoption in the Saudi Arabian healthcare supply chain, based on a review of the literature and brainstorming with experts from industry and academia. The contextual relationship between the identified barriers was developed using interpretive structural modeling (ISM), and the results were used to determine the driving and dependence power of the barriers using MICMAC analysis. The findings of the study suggest that the legal and regulatory environment and the lack of IT infrastructure are the two most important barriers to IoT adoption in the Saudi Arabian healthcare supply chain. Other important barriers include the lack of awareness and expertise among healthcare professionals, the lack of resources, and resistance to change. The findings of this study will be useful for decision-makers in the Saudi Arabian healthcare sector to understand the barriers to IoT adoption and to develop strategies to overcome these barriers.

Keywords
IoT Adoption, Smart Healthcare, Interpretive Structural Modelling (ISM), Healthcare Supply Chain, Radio Frequency Identification (RFID).

1. Introduction
As the global healthcare industry evolves, the Internet of Things (IoT) has emerged as a transformative force, promising to enhance efficiency, reduce costs, and improve patient care. In Saudi Arabia, the healthcare supply chain is exploring IoT adoption to leverage these benefits and address challenges such as an aging population and service delivery inadequacies. The motivation of this paper, in alignment with Saudi Vision 2030, our vision for the integration of the Internet of Things (IoT) in the healthcare supply chain is to achieve a pioneering and transformative healthcare system. This system is envisioned to be highly efficient, technologically advanced, and patient-centric, effectively contributing to the Kingdom's aspirations for innovation and excellence in healthcare. We envisage a future where the healthcare supply chain in Saudi Arabia is characterized by its agility, responsiveness, and integration of cutting-edge IoT technology. The envisioned state is one where real-time data analytics from IoT devices drive decision-making processes, optimize resource allocation, and ensure that the highest quality of care is delivered across all healthcare facilities. Our vision extends to the establishment of a comprehensive network of connected devices and systems, enabling seamless operations from pharmaceutical manufacturing to patient bedside care. We aim to foster an environment where continuous learning and adaptation are the norms, with IoT at the core of a resilient healthcare infrastructure capable of withstanding future challenges. By realizing this vision, we anticipate that Saudi Arabia will

not only elevate the standard of its healthcare services but also position itself as a global leader in healthcare innovation, setting a benchmark for others to follow in the transformative journey of healthcare digitization. This study investigates the barriers to IoT adoption in the Saudi healthcare supply chain using the ISM MICMAC approach. In recent years, advancements in telecommunications, microelectronics, and automation have broadened the potential of healthcare supply chains. The integration of ICT and internet technologies has become critical for modern healthcare infrastructure and governance, contributing to the development of smart healthcare systems. IoT stands at the forefront of this transformation, enabling a sophisticated network of sensors and devices that foster efficiency and facilitate clear information exchange. This paper identifies 14 potential barriers to IoT adoption through literature review and expert consultation, employing interpretive structural modelling (ISM) and MICMAC analysis to understand these challenges' interrelations and impacts. Key barriers include legal and regulatory constraints, inadequate IT infrastructure, lack of awareness among healthcare professionals, and resistance to change. Through this research, we aim to provide insights for decision-makers to strategize effectively for IoT integration, offering a comprehensive view of the underlying obstacles and paving the way for a more resilient and advanced healthcare supply chain in Saudi Arabia. The problem statement of this paper is identifying barriers and their interrelationships in adopting IoT in the Saudi Arabian healthcare supply chain.

1.1 Objectives

1. Identify and interpret the barriers to IoT adoption within the Saudi healthcare supply chain context.
2. Utilize Interpretive Structural Modelling (ISM) to map the barriers and their interrelationships.
3. Conduct a MICMAC analysis to categorize the barriers into clusters, aiding in the prioritization of managerial actions.
4. Discuss the study's implications and suggest avenues for future research.

2. Literature Review

The Internet of Things (IoT) is expected to be a promising futuristic technology platform that will have a significant impact on the Saudi Arabian healthcare supply chain. IoT adoption and implementation is an essential phase for research purposes, as it offers several benefits and value addition to the healthcare supply chain by integrating upcoming technologies into its systems. However, the healthcare industry in Saudi Arabia still faces many obstacles in effectively implementing IoT concepts in its supply chain. Therefore, it is essential to have an efficient literature review of IoT adoption barriers to develop a structural model for the Saudi Arabian healthcare supply chain. In this paper, the literature review is completed by the following steps: Identifying research objectives, recognizing keywords and collecting databases, Selecting well-matched articles and journals, and finally Extracting data. To identify the research objective, this research develops questions associated with the smart healthcare management system opportunities, challenges, and the techno-economic factors affecting the adoption of IoT in the healthcare management system. To collect databases, research articles and field reports related to IoT in different domains available in prominent sources like Scopus and Web of Science were considered. The search keyword used included terms like IoT adoption, RFID, smart healthcare, healthcare supply chain, e-health, Health 4.0, opportunities, and challenges in modern healthcare, according to Desingh et al (2021). These expressions had to be available in the titles and abstracts to validate the keywords. The selected publisher (Elsevier, Springer, IEEE, Taylor and Francis, Wiley, and Emerald Insights) and journals that contain the most specific articles in the search were included in the database. Also, a few industry reports, trade magazines, and news articles were also referred to for more information on the IoT benefits related to different industry scenarios. The keyword search resulted in a total of 465 articles, out of which 264 journals and industrial research reports were finalized. The researcher thoroughly examined the final selected journal abstracts after removing duplicates. Only the papers related to the research objectives of the study were chosen. In the end, the efficient review process summarized to 158 research articles that effectively covered the objective of the research, and that was used for the literature review. Based on the above steps, initially, around 29 critical barriers which are related to IoT adoption barriers in the developing country context of different industry scenarios. An expert team consisting of 12 members was formed and each expert was requested to rank the barriers which need to be considered deemed critical for IoT adoption process. From the final cumulative result, the highest number of frequency given by the experts was chosen. As an outcome of this, 14 critical barriers were identified which are related to IoT adoption in the developing country context. After having a brainstorming session and personal interview with these experts, and based on their opinions, 14 barriers were finalized in the data collection method chapter. Some of the 29 barriers we have identified are as follows, Lack of awareness about IoT benefits in the healthcare domain (Alam and Mehtab 2022), Difficulty in big data management (Alotaibi and Shoayee 2018), Socioeconomic impacts (Banka and Manisha 2022), Legal and regulatory standards (Brown and Justine 2014), Interoperability and standardization (Brad and

Genereaux 2021), Lack of qualified employees (Edward E and Gordon 2013), Data storage and processing (Raja and Jayaraman 2015), Lack of knowledge management system (Mittal et al 2023), High implementation and operating cost (Ramakrishna and Yanamandra 2018), Government support and regulations (Ben and Shneiderman 2022), and Lack of security & privacy concerns (Zhang and Rui 2021).

IoT is a business system where sensors and digitally embedded sensors exchange data over the internet. According to (Li, B. H., Dai, H. and Wang, H. 2016), it is a promising technology platform that can help achieve sustainable benefits in the healthcare supply chain. IoT was first proposed by Ashton and Brock, who founded the Auto-ID Centre at MIT. According to (Li, B. H., Dai, H. and Wang, H. 2016), auto-ID refers to any type of communication and identification technology for industrial applications, such as tracking, tracing, automation, and error reduction. Any physical object can be tracked as it moves from one place to another. IoT also refers to the network of physical things that combines wireless networks, electronic devices, software, internet connection, and sensors to communicate and exchange data with people, products, and other physical things.

3. Methods

The objective of this research project is to model IoT-related hurdles. The ISM method was applied to accomplish the goal. This is because of its capacity to handle interrelated components, like the IoT barriers discussed here, create connections between them, and represent the complexity of those connections and the issue being studied. Researching IoT hurdles necessitates input from subject matter experts and decision-makers who are actively involved in the healthcare supply chain strategy and in charge of creating the overall digital strategy and establishing the necessary frameworks. This guarantees the accuracy of the data entered into the modelling and analysis processes, which in turn guarantees the accuracy of the results. Owing to the nature of the research, a select group of experts met the requirements and were asked to contribute. However, by including feedback from a small group of experts, the ISM technique also has the advantage of improving comprehension of complicated situations and synthesizing links among its aspects. The method used by the ISM technique is methodical and iterative, utilizing graph theory and Boolean algebra. As shown in Figure 1, there are seven stages that can be taken to perform the ISM approach and its analysis. The accompanying research process flowchart, shown in Figure 2, indicates that these seven phases were used for this investigation.

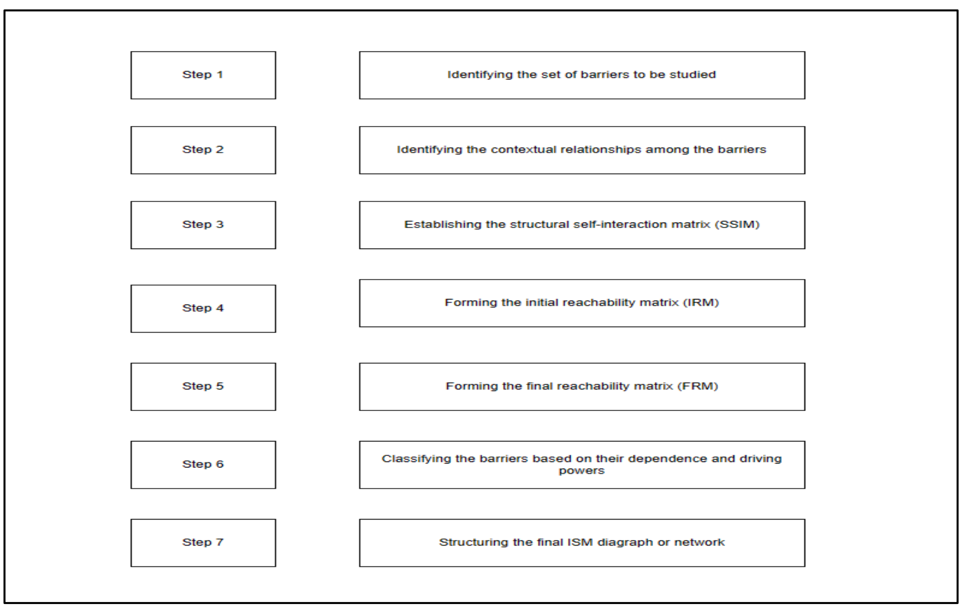

Figure 1. Seven implementation steps of the ISM techniques

To accomplish the goal of this investigation, the research technique flowchart shown in Figure 2 was adhered to. The first step of the ISM approach (Figure 1) involved a thorough literature review to identify the fourteen IoT hurdles described in data collection chapter. The initial reachability matrix (IRM) is conducted by converting the data from each SSIM cell into binary digits (i.e., 0 and 1) in the initial reachability matrix based on the symbols, the SSIM matrix is transformed into an initial reachability matrix. The final reachability matrix (FRM) has been obtained after conducting transitivity rule on the initial reachability matrix (IRM), which states that if barrier A is linked to C and barrier C is connected to D, then it may be assumed that barrier A should be related to D, is applied to compute the final reachability matrix from the initial reachability matrix. With the Excel program, the transitivity study was carried out. Table 1 displays the final reachability matrix together with the transitivity correlations. The level partitioning has been conducted from the reachability set and antecedent set for every barrier are derived from the final reachability matrix. The barriers that it may assist in overcoming and the barrier itself make up the reachability set for a given barrier. Comparably, the barriers themselves and any additional barriers that might aid in their achievement make up the antecedent set. Next, for every barrier to IoT adoption, the intersection of these sets is determined. This would not help attain any further obstacles above their own level. The top level in the ISM model is filled by the barriers, whose reachability and intersection sets are the same. It is separated from the other obstacles following the identification of the top-level barriers.

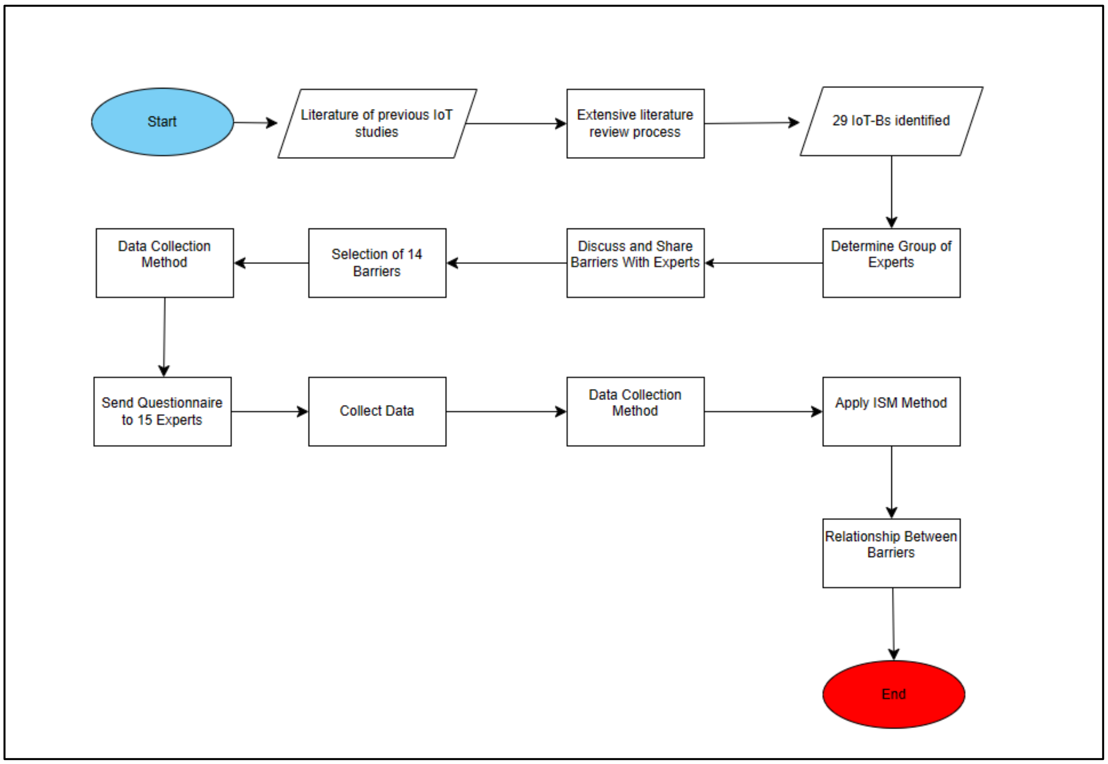

Figure 2**.** Project methodology flowchart

Table 1. Rules of constructing (SSIM) and (IRM)

Scenario	Direction of Relationship	SSIM Entry	IRM Entries	
	(IoT-Bi, IoT-Bj) *	**(IoT-Bi, IoT-Bj) ***	**(IoT-Bi, IoT-Bj) ***	**(IoT-Bi, IoT-Bj) ***
1	**IoT-Bi → IoT-Bj**	**V**	1	0
2	**IoT-Bi ← IoT-Bj**	**A**	0	1
3	**IoT-Bi ↔ IoT-Bj**	**X**	1	1
4	**IoT-Bi × IoT-Bj**	**O**	0	0

* i and j indicate the barrier number in a row and column in the associated matrix, respectively.

4. Data Collection

Our research has identified a number of barriers to the implementation of the Internet of Things (IoT) in the Saudi Arabian healthcare supply chain from our literature review. To verify these barriers, we will conduct interviews and surveys with experts in the Saudi Arabian healthcare sector. We believe that this expert validation is essential to ensuring that our research is relevant and impactful. By understanding the barriers to IoT implementation, we can develop targeted solutions to address them and accelerate the adoption of this transformative technology in the Saudi Arabian healthcare sector. For example, interview has been conducted with healthcare professionals from a variety of backgrounds to get their perspectives on the barriers to IoT implementation. We will also conduct a survey of healthcare managers to gather data on the specific needs of their organizations and the challenges they face in implementing IoT. Additionally, we will convene a focus group of experts to discuss specific IoT solutions and get their feedback on the barriers to their implementation. Finally, we will conduct case studies of successful IoT implementations in other healthcare settings to identify best practices and lessons learned. Expert validation will be invaluable to the research and will help to develop a more comprehensive and nuanced understanding of the barriers to implementing IoT in the Saudi Arabian healthcare supply chain. To identify the barriers that have a significant impact on the healthcare supply chain in the Kingdom of Saudi Arabia, we conducted a survey of 15 experts from a variety of backgrounds, including professors, managers, engineers, Sr. Managers, and academicians. The results of the survey showed that the following 14 barriers as shown in Table 2 have a significant impact on the healthcare supply chain in Saudi Arabia. The findings of this survey provide valuable insights into the barriers that are preventing the adoption of IoT in the Saudi Arabian healthcare supply chain. By addressing these barriers, policymakers and healthcare organizations can accelerate the adoption of this transformative technology and improve the efficiency and effectiveness of the healthcare supply chain.

Table 2. List of IoT adoption barriers in the healthcare supply chain

S.No	**IoT Adoption Barriers**
1	Lack of security & privacy concerns
2	Data confidentiality
3	High implementation and operating cost
4	Difficulty in big data management
5	Data storage and processing
6	Lack of awareness about IoT benefits in the healthcare domain
7	Lack of knowledge management system
8	Complex architecture
9	Lack of qualified employees
10	Energy management
11	Interoperability and standardization
12	Socioeconomic impacts
13	Government support and regulations
14	Legal and regulatory standards

5. Results and Discussion

5.1 Numerical Results

The initial reachability matrix in Table 3 is obtained by investigating the relationships between system parts, as stated in the Structural-self interaction matrix in Table 4. This matrix demonstrates how each element influences or is influenced by others. An Excel software is used to improve the initial reachability matrix. Excel's computational capabilities allow it to conduct computations and modifications on the matrix, resulting in a refined final reachability matrix in Table 5. Excel's analytical features has been used to conduct a transitivity analysis. Excel can be used to get significant insights into the accessibility and interconnections of system elements.

Table 3. Structural-Self Interaction Matrix

IOT adaptation barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		X	V	A	V	V	V	A	O	O	A	A	O	A
2			A	A	V	O	V	V	O	A	O	O	V	A
3				A	A	A	V	X	V	A	X	O	V	A
4					V	V	O	O	O	V	V	O	V	O
5						A	V	V	V	A	V	V	O	A
6							V	V	O	A	V	V	O	A
7								A	O	A	O	O	A	A
8									A	A	V	A	O	A
9										A	V	V	O	A
10											V	V	O	X
11												X	O	A
12													O	O
13														A
14														

- In the initial reachability matrix, the cell (i, j) entry becomes 1 and the cell (j, i) entry becomes 0 if the data in the cell (i, j) in the SSIM is V.
- In the initial reachability matrix, the cell (i, j) entry becomes 0 and the cell (j, i) entry becomes 1 if the data in the cell (i, j) in the SSIM is A.
- The entries in both cells (i, j) and (j, i) in the initial reachability matrix become 1 if the data in the SSIM cell (i, j) is X.
- The entries in cells (i, j) and (j, i) in the original reachability matrix become 0 if the data in the SSIM cell (i, j) is O.

Table 4. Initial reachability matrix

IOT adaptation barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	1	1	0	1	1	1	0	0	0	0	0	0	0
2	1	1	0	0	1	0	1	1	0	0	0	0	1	0
3	0	1	1	0	0	0	1	1	1	0	1	0	1	0
4	1	1	1	1	1	1	0	0	0	1	1	0	1	0
5	0	0	1	0	1	0	1	1	1	0	1	1	0	0
6	0	0	1	0	1	1	1	1	0	0	1	1	0	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	1	0	1	0	0	0	1	1	0	0	1	0	0	0
9	0	0	0	0	0	0	0	1	1	0	1	1	0	0
10	0	1	1	0	1	1	1	1	1	1	1	1	0	1
11	1	0	1	0	0	0	0	0	0	0	1	1	0	0
12	1	0	0	0	0	0	0	1	0	0	1	1	0	0
13	0	0	0	0	0	0	1	0	0	0	0	0	1	0
14	1	1	1	0	1	1	1	1	1	1	1	0	1	1

Table 5. Final reachability matrix

IoT adoption barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	1	1	0	1	1	1	1*	1*	0	1*	1*	1*	0
2	1	1	1*	0	1	1*	1	1	1*	0	1*	1*	1	0
3	1*	1	1	0	1*	0	1	1	1	0	1	1*	1	0
4	1	1	1	1	1	1	1*	1*	1*	1	1	1*	1	1*
5	1*	1*	1	0	1	0	1	1	1	0	1	1	1*	0
6	1*	1*	1	0	1	1	1	1	1*	0	1	1	1*	0
7	0	0	0	0	0	0	1	0	0	0	0	0	0	0
8	1	1*	1	0	1*	1*	1	1	1*	0	1	1*	1*	0
9	1*	0	1*	0	0	0	1*	1	1	0	1	1	0	0
10	1*	1	1	0	1	1	1	1	1	1	1	1	1*	1
11	1	1*	1	0	1*	1*	1*	1*	1*	0	1	1	1*	0
12	1	1*	1*	0	1*	1*	1*	1	0	0	1	1	0	0
13	0	0	0	0	0	0	1	0	0	0	0	0	1	0
14	1	1	1	0	1	1	1	1	1	1	1	1*	1	1

Note 1* shows transitivity

The final reachability matrix is used to calculate the reachability set and antecedent set for each barrier. The hurdles that it may help overcome, as well as the barrier itself, comprise the reachability set for a given barrier. The antecedent set consists of the barriers themselves as well as any extra hurdles that may aid in their attainment. Next, for every barrier to IoT adoption, the intersection of these sets is established. This would not assist them overcome any additional difficulties above their current level. The barriers, whose reachability and intersection sets are the same, fill the top level of the ISM model. Following the identification of the top-level barriers, it is separated from the other impediments. In the first iteration of this study, for example, the reachability set and intersection set of barrier 7 are identical. The process is repeated until all of the obstructions are split, and these impediments are removed in subsequent iterations. This method is done until the levels of each IoT adoption barrier are determined. The indicated levels contribute in the building of the digraph and the final model of the ISM. Table 6 shows the level partitioning and iteration.

Table 6. Level partitions and iterations

Barriers	Reachability Set	Antecedent Set	Intersection Set	Level
Iteration I				
7	7	1,2,3,4,5,6,7,8,9,10,11,12,13,14	7	1
Iteration II				
12	1,2,3,5,6,8,11,12	1,2,3,4,5,6,8,9,10,11,12,14	1,2,3,5,6,8,11,12	2
13	13	1,2,3,4,5,6,8,10,11,13,14	13	2
Iteration III				
1	1,2,3,5,6,8,9,11	1,2,3,4,5,6,8,9,10,11,14	1,2,3,5,6,8,9,11	3
3	1,2,3,5,8,9,11	1,2,3,4,5,6,8,9,10,11,14	1,2,3,5,8,9,11	3
8	1,2,3,5,6,8,9,11	1,2,3,4,5,6,8,9,10,11,14	1,2,3,5,6,8,9,11	3
9	1,3,8,9,11	1,2,3,4,5,6,8,9,10,11,14	1,3,8,9,11	3
11	1,2,3,5,6,8,9,11	1,2,3,4,5,6,8,9,10,11,14	1,2,3,5,6,8,9,11	3
Iteration IV				
2	2,5,6	2,4,5,6,10,14	2,5,6	4
5	2	2,4,5,6,10,14	2	4
Iteration V				
6	6	4,6,10,14	6	5
Iteration VI				
10	10,14	4,10,14	10,14	6
14	10,14	4,10,14	10,14	6
Iteration VII				
4	4	4	4	7

5.2 Graphical Results

The final reachability matrix serves as the basis for the ISM structure model. An arrow pointing from barrier i to barrier j, and vice versa, indicates if there is a relationship between the barriers. A structural model is created utilizing the final reachability matrix and its resulting levels. A directed graph, often known as a digraph, is the final graph as shown in Figure 3. To transform the digraph into an ISM model, the elemental nodes are substituted. The digraph is ultimately transformed into the ISM-based model when the transitivity has been eliminated. The ISM structural model. In the ISM model, all the barriers are categorized in seven different levels. It can be inferred that 'Difficulty in big data management (B4)' is the most significant barriers of IoT adoption in Saudi Arabia healthcare supply chain, as they come at the base of the ISM hierarchy. 'Lack of knowledge management system (B7), is the barriers which most reflect the dependent tendency of the other barriers. The barriers is previewed at the top of the hierarchy. Further these barriers are classified with the help of MICMAC analysis.

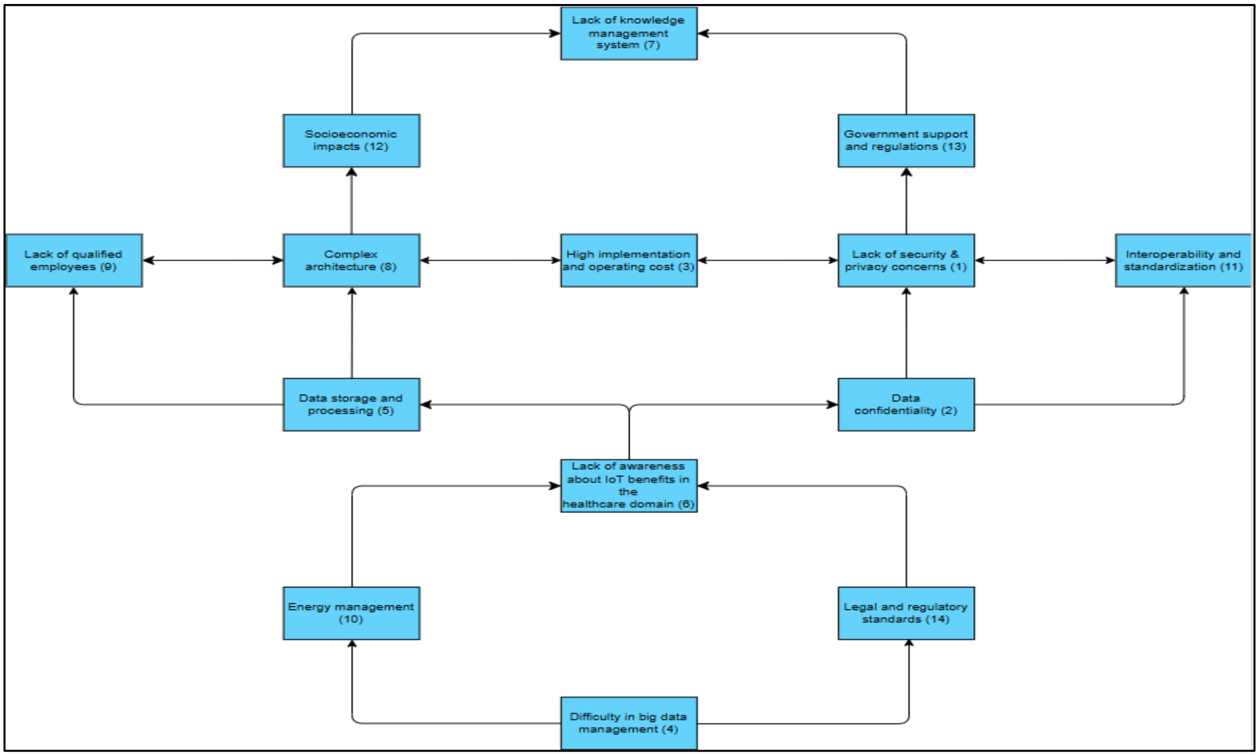

Figure 3. ISM Model Digraph

The healthcare supply chain is a crucial industry that provides top-notch care and services to people worldwide. Nation on the planet. It must always be enhanced, particularly in light of healthcare administration. Framework. Although India's contemporary healthcare supply chain is expanding, there are still certain gaps, such as inadequate IT infrastructure. In addition, their performance is being impacted by the cost of technology. Several wealthy nations are implementing the Internet of Things, an emerging technology, to provide better healthcare solutions. Due to several hurdles and requirements, the Saudi Arabian healthcare supply chain has a relatively low Internet of Things penetration rate. Special consideration. In this article, we've listed 14 obstacles to IoT adoption in the in the Saudi Arbian healthcare supply chain, through an assessment of the literature and the insights of academic and industry leaders. To ascertain how the barriers related to one another, the ISM methodology was used. The findings show that the barriers have positioned themselves into seven deferent levels and IoT adoption barrier 4 (Difficulty in big data management) occupied the first level. IoT adoption barrier 10 (Energy management), barrier 14 (Legal and regulatory standards) occupied level 2. IoT adoption barrier 6 (Lack of awareness about IoT benefits in the healthcare domain) occupied level 3. IoT adoption barrier 5 (Data storage and processing), barrier 2 (Data confidentiality) occupied level 4. IoT adoption barrier 9 (Lack of qualified employees), barrier 8 (Complex architecture), barrier 3 (High implementation and operation cost), barrier 1 (Lack of security & privacy concerns), barrier 11 (Interoperability and standardization) occupied level 5. IoT adoption barrier 12 (Socioeconomic impacts), barrier 13 (Government support and regulations) occupied level 6. Finally, IoT adoption barrier 7 (Lack of knowledge and management system) occupied level 7. In order to analyze the dependence and driving power of the IoT Saudi Arabian health care adoption barriers, MICMAC analysis have been conducted. Barriers are classified into four clusters and the driving power and dependence power for the suggested performance measures is shown in Figure 4. MICMAC analysis diagram.

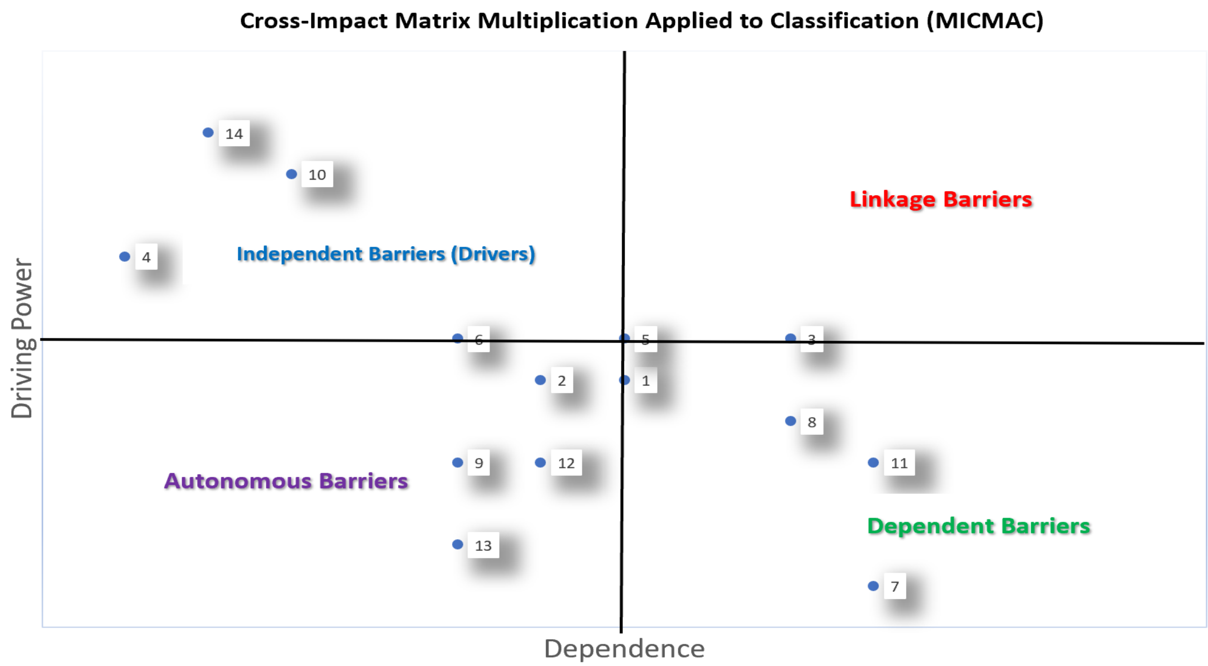

Figure 4. Cluster diagram

The autonomous barriers in the first quadrant are weak drivers and weak dependents that don't have a big impact on the system. The system, which is situated in the lower left corner in the cluster diagram in Figure 4, is somewhat isolated from the autonomous measures. Barriers included in this section are barrier 2 (Data confidentiality), barrier 9 (Lack of qualified employees), barrier 12 (Socioeconomic impacts), barrier 13 (Government support and regulations) are located in this cluster. The mentioned autonomous barriers are not significant in the process of adopting IoT in Saudi Arabia for the healthcare supply chain, and can be at the bottom in priority hierarchy.

The dependent barriers, which are represented in the diagram's lower right corner, make up the second quadrant. They have significant dependence power and weak drive. Because these obstacles are dependent on the other barriers, all other barriers must assist the dependent barriers in order to minimize their impact on the adoption of IoT in the Saudi Arabian healthcare supply chain. Four barriers, barrier 1 (Lack of security & privacy concerns), barrier 11 (Interoperability and standardization), barrier 8 (Complex architecture), barrier 7 (Lack of knowledge and management system) are located in this cluster. The results show that barriers 1, 7, 8, and 11 are weakly driven but highly reliant on the system's other input barriers.

Linkage barriers with high reliance power and strong driving power are seen in the third quadrant. The diagram's upper right corner is where this cluster is located. The barriers arranged in this cluster symbolize the coordinated actions of a highly dependent and driving person. Since they are the most crucial components of the system, any action taken in relation to them will have an impact on it as a whole. Two barriers, barrier 3 (High implementation and operation cost), barrier 5 (Data storage and processing) are located in this cluster. Due to this, these previously mentioned barriers are out of balance, which could have a favorable or negative impact on the healthcare supply chain's ability to successfully adopt IoT.

The upper left corner of the diagram represents the fourth quadrant, which is made up of independent barriers with strong driving power and weak dependence power. We call the barriers arranged in this cluster "Driver Barriers". Four barriers, Barrier 6 (Lack of awareness about IoT benefits in the healthcare domain), Barrier 4 (Difficulty in big data management), Barrier 10 (Energy management), Barrier 14 (Legal and regulatory standards) are located in this cluster. They serve as significant roadblocks to adoption. This obstacle must be given careful consideration by those making decisions. Any modifications to this barrier will affect all other barriers across all levels of the hierarchy. In this case, barriers 4, 6, 10, and 14 must be considered in the top of the priority hierarchy.

5.3 Proposed Improvements

Suggestions for removing barriers to Internet of Things (IoT) adoption in Saudi Arabia's healthcare supply chain become vital requirements for the Kingdom's healthcare ecosystem. As a result of this research's thorough understanding of the obstacles preventing IoT technologies from being successfully integrated into the healthcare supply chain, it have put forth a number of important recommendations to help stakeholders, legislators, and decision-makers navigate this revolutionary journey:

1. Invest in Education and Awareness: It is critical to address Barrier 6 (the lack of knowledge about the advantages of IoT in the healthcare sector). Prioritizing efforts should be made to inform the public, administrators, and healthcare professionals about the potential benefits of IoT in enhancing patient care and supply chain effectiveness.
2. Energy Management: Barrier 10 emphasizes how crucial it is to maximize energy usage in Internet of Things systems. To lessen operating expenses and their negative effects on the environment, initiatives to encourage energy-efficient IoT devices and practices should be investigated.
3. Legal and Regulatory Compliance: Barrier 14 highlights how crucial it is to follow all applicable laws and regulations. To guarantee compliance with changing legislation pertaining to the Internet of Things, healthcare institutions should set up strict compliance systems and work with regulatory bodies.
4. Address Cost Concerns: One major obstacle is Barrier 3, which is the high implementation and operation costs. In order to get over this, stakeholders should look at IoT solutions that are affordable and think about providing grants or subsidies to encourage investments, especially from smaller healthcare institutions.
5. Strengthen Data Management: Robust data management techniques are required, given the importance of data processing and storage (Barrier 5) and data confidentiality (Barrier 2). Creating scalable, compliant, and secure data processing and storage solutions ought to be at the forefront of IoT adoption initiatives.

6. Conclusion

This project explored the challenges of implementing the Internet of Things (IoT) in Saudi Arabia's healthcare supply chain, identifying 14 key obstacles such as data security and lack of skilled workforce. These challenges were grouped into four clusters, highlighting different aspects of IoT adoption. The study provides a roadmap for overcoming these barriers to leverage IoT benefits like enhanced healthcare access and cost reduction. It emphasizes the need for a strategic approach to make Saudi Arabia a leader in using IoT for healthcare improvement, offering insights for IoT adoption in developing countries.

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Biographies

Ammar Y. Alqahtani, PhD, is an associate professor of Industrial Engineering at King Abdulaziz University in Jeddah, Saudi Arabia. He received his BS degree with first honors from the Industrial Engineering Department of King Abdulaziz University, Jeddah, Saudi Arabia, in May 2008. Being awarded with a full scholarship by the King Abdulaziz University (KAU), he received his MS degree in Industrial Engineering from Cullen College of Engineering, University of Houston. In September 2012, he started his PhD studies in Industrial Engineering at Northeastern University, Boston, Massachusetts. He received his PhD degree in 2017. He has been employed as a faculty member by King Abdulaziz University since December 2008. His research interests are in the areas of environmentally conscious manufacturing, product recovery, reverse logistics, closed-loop supply chains (CLSC), sustainable operations and sustainability, simulation and statistical analysis and modeling with applications in CLSC and multiple life-cycle products. He has published two books, titled Warranty and Preventive Maintenance for Remanufactured Products Modeling & Analysis and Responsible Manufacturing Issues Pertaining to Sustainability. He has coauthored several technical papers published in edited books, journals and international conference proceedings. At Northeastern University, he won the Alfred J. Ferretti research award. He also received the 33rd Quality.

Ibrahim Alkathiri, a determined and meticulous senior industrial engineering student from Jeddah, Saudi Arabia, was born on August 22, 2001. With exceptional communication, problem-solving, and analytical skills, he excels in multitasking and applying lean manufacturing principles to drive operational improvements. In his senior project, Ibrahim and his team focused on identifying and interpreting barriers to implementing IoT in the Saudi healthcare supply chain. They recognized IoT's potential to enhance efficiency, traceability, and patient care, conducting extensive research and collaborating with healthcare professionals. This allowed them to pinpoint key obstacles within the existing supply chain system. Leveraging his previous learning and experiences, Ibrahim successfully analyzed challenges related to integrating IoT devices, establishing secure data communication protocols, and interpreting vast volumes of data for meaningful insights. By understanding the interrelationships between these barriers, Ibrahim and his team aimed to gain a comprehensive understanding of what impedes widespread IoT adoption in the Saudi healthcare supply chain.

Abdulrahman Jamaluddin, born on June 13, 2001, in Al-Fisalyah, Jeddah, Saudi Arabia, is a senior Industrial Engineering student acclaimed for his work on interpretive structural modeling in the context of IoT barriers in the healthcare supply chain in Saudi Arabia. His academic journey, marked by a deep interest in systems analysis and logistics, led him to this groundbreaking project, which demonstrates his ability to blend advanced technological concepts with practical supply chain solutions. With his roots in a city known for its dynamic business environment, Abdulrahman's contributions reflect not only his technical expertise but also his commitment to enhancing healthcare services in his home country. As he approaches the completion of his undergraduate studies, he stands out as a promising hard working talent in the field, ready to make significant strides in Industrial Engineering and beyond.

Hamza Khadawardi, born on February 23, 2001, has emerged as a noteworthy figure in the field of Industrial Engineering, particularly in the realm of healthcare supply chain research. As a senior student, Hamza has concentrated his academic efforts on understanding and analyzing the barriers in the healthcare supply chain, primarily through extensive literature review. His methodical approach to dissecting and synthesizing existing research has provided valuable insights into the complexities and challenges within this sector. Born and raised in an environment that values education and intellectual inquiry, Hamza has utilized his skills to critically evaluate and interpret various sources, contributing significantly to the understanding of how these barriers impact the efficiency and effectiveness of supply chains in healthcare. His work stands as a testament to his analytical prowess and dedication to advancing the field of Industrial Engineering through rigorous research and scholarship..

Waleed Alghmadi, born on May 10, 2000, is a senior Industrial Engineering student recognized for his expertise in data analysis, particularly using Excel. His skill in interpreting and managing complex data sets has distinguished him in the field of healthcare supply chain management. Born into a generation that has witnessed rapid technological advancement, Waleed has harnessed these changes to develop a deep understanding of data analytics tools and techniques. His proficiency with Excel, a crucial tool in engineering analysis, has enabled him to provide insightful observations and solutions to intricate problems in the healthcare supply chain. Waleed's ability to manipulate large data sets, create meaningful visualizations, and derive actionable insights has made him an invaluable asset to his academic and project teams.