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Investigating Factors Influencing Blockchain Adoption in Saudi Healthcare Data Management

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by

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ABSTRACT

Title: Investigating Factors Influencing Blockchain Adoption in Saudi Healthcare Data Management

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Blockchain technology can potentially address security and privacy issues concerning the collection, storage, and sharing of healthcare data. However, its adoption within the healthcare sector is nascent in Saudi Arabia. This underutilization prompted our investigation into the determinants influencing blockchain adoption, intending to fully empower the Saudi healthcare sector to leverage blockchain capabilities. To achieve this, an extensive literature review was conducted to identify the pivotal factors encompassing technology, organization, and environment (TOE) that affect the successful implementation of blockchain technologies in managing healthcare data within the Saudi context. Utilizing the TOE framework, this study formulated three hypotheses concerning the adoption of blockchain technology. Subsequently, a quantitative analysis was undertaken through an online survey distributed among healthcare organizations in Saudi Arabia. We obtained responses from 129 valid questionnaires and employed a partial least squares structural equation model (PLS-SEM) for analysis and hypothesis testing. The results show that technological and organizational factors significantly influence the adoption of blockchains, whereas environmental factors have no significance. This study contributes significantly to bridging a critical gap in the academic literature by clarifying the factors influencing blockchain adoption in healthcare data management in Saudi Arabia. Our findings serve as valuable guidelines for decision-makers contemplating the adoption of blockchain technology in healthcare data management, thus facilitating the effective navigation of associated challenges.

Table of Contents

List of Figures

List of Tables

List Abbreviations

EMR Electronic Medical Record

HIS Health Information System

TOE Technical, Organizational, and Environmental Framework

IT Information Technology

FDA Food and Drug Administration

HIPAA Health Insurance Portability and Accountability Act

MOH Ministry of Health

NPHIES National Platform for Health and Insurance Exchange Services

DoS Denial of Service

RC Registrar Contract

PPR Patient-Provider Relationship Contract

SC Summary Contract

IS Information Systems

TAM Technology Acceptance Model

UTAUT Unified Theory of Acceptance and Use of Technology

SMEs Small and Medium Enterprises

PLS-SEM Partial Least Squares Structural Equation Modeling

IRB Research Involving Human Participants

RV Relative Advantage

CX Complexity

HR Healthcare Providers' Readiness

LS Leadership Support

GS Government Support

CP Competitive Pressure

AVE Average Variance Extracted

BI Behavioral Intention

$\mathbf{R^2}$ Coefficient of Determination

f^2 Effect Size

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Dedication

I dedicate this thesis to my beloved parents, who have inspired me to pursue education with their unending love, constant support, and selfless sacrifices. To my dear husband, for whose persistent assistance and selfless actions have allowed me to commit to my studies fully, and for which I am incredibly grateful to my treasured children. Even though this journey has taken a lot of time and attention, please know that my goal has always been to provide our family with a better future.

Chapter 1

Introduction

Medical data fall within the scope of a data-sensitive domain. Historically, these data have been archived in a tangible, paper-based format. This conventional practice carries the potential consequence of medical decisions being made without access to comprehensive information, thereby necessitating the repetition of diagnostic tests due to information gaps or the fragmentation of data across disparate healthcare facilities.

However, the progression of information technology has facilitated the healthcare sector's replacement of traditional paper-based formats with electronic medical records (EMRs). EMRs improve patient care, advance disease diagnosis, and ensure continuous accessibility to patient health information. These records, encompassing a patient's personal and medical information, are generated, disseminated, and archived by healthcare professionals. EMRs are then securely stored within a hospital's database, which may necessitate retrieval by a physician in another department within the same network.

To facilitate the management of EMRs, a graphical user interface called a health information system (HIS) is developed, typically coupled with a backend database in a centralized configuration (1). In the Kingdom of Saudi Arabia (KSA), HISs vary from one hospital to another. While some hospitals rely on traditional paper-based medical records, a significant number are now utilizing independent EMR systems. For instance, select hospitals in

Saudi Arabia, such as King Fahad National Guard Hospital and King Faisal Hospital, have taken steps to implement EMR systems (2). These systems are designed to facilitate the exchange of medical data among hospitals (3). However, the lack of standardized medical data storage methods poses a challenge to seamless medical data sharing among healthcare institutions, thus negatively affecting patients and healthcare providers. Additionally, the sharing of medical data across the Internet and various servers or clouds situated outside the secure healthcare institution's environment has raised concerns about the privacy and security of this data (4). The Cybersecurity Quarterly Bulletin for the fourth quarter of 2020, released by the Saudi National Cybersecurity Authority, indicates that the healthcare sector ranks second globally among the most targeted sectors, accounting for 14% of them. Unauthorized access stands out as the primary threat in the first rank, while information leakage ranks fourth within the Kingdom of Saudi Arabia (KSA) (5). An illustrative example is the compromise of confidential health information of 34.9 million U.S. citizens during the Health Insurance Portability and Accountability Act breaches in 2019 (6). Furthermore, medical data are stored in a centralized database, rendering them susceptible to single points of failure and hacking (7). Consequently, healthcare organizations must develop strategies to strengthen the security of healthcare data to maintain a trusting relationship between patients and healthcare providers (8). These strategies can be developed by enhancing the technology used, which may play a crucial role in finding solutions to different security and privacy threats to healthcare data management. An example of advanced technology is blockchain technology.

A blockchain is a time-stamped and immutable collection of data records stored in a decentralized manner on a network of computers (9). The healthcare sector in particular can benefit significantly from blockchain technology due to its features of transparency, immutability, traceability, and decentralization (10).

While the potential advantages of integrating blockchains into the healthcare sector are considerable, their adoption remains limited or unsuccessful. An analysis of the blockchain literature revealed that the utilization of blockchain technology in healthcare data management is mainly limited to proof of concepts, white papers, and products with a small user community (11). This slow adoption can be attributed to multiple factors, including healthcare organizations' hesitation to embrace blockchains, a lack of recognition regarding their potential value, and an absence of organizational preparedness for their adoption (12).

Before adopting any new technology, it is extremely important to study the factors that influence its integration from various perspectives to avoid failure. However, the factors that influence the integration of blockchain technology with healthcare data management have received relatively limited attention in academic research. Consequently, there is a need for additional studies to explore the factors influencing the adoption of blockchains in healthcare data management, particularly in the KSA. This involves examining user acceptance of new systems, as well as assessing compatibility with existing systems.

This study aims to investigate the factors that influence the adoption of blockchain technology in Saudi healthcare data management. In doing so, it seeks to develop a theoretical framework that focuses on the technical, organizational, and environmental (TOE) factors that impact the adoption of blockchain technology in Saudi healthcare data management and to empirically test it. Furthermore, it delivers valuable insights for stakeholders in the Saudi healthcare sector, offering an understanding of the factors influencing blockchain adoption in Saudi healthcare data management. The findings aim to enhance the decision-making processes of decision makers regarding blockchain adoption in Saudi healthcare data management and to broaden its application scope.

1.1 Problem Statement

Medical data contain sensitive personal and medical information; therefore, they are highly susceptible to cyberattacks, which can compromise the confidentiality, integrity, or availability of the data.

The failure to adequately safeguard the security and privacy of medical data may result in significant financial and legal consequences for healthcare organizations. Despite the sophistication of current healthcare information systems, they remain vulnerable to security breaches. Consequently, healthcare institutions must enhance their services by adopting cutting-edge technologies, such as blockchains, which boost security measures.

Blockchain technology's unique attributes, such as immutability, transparency, and decentralization, have the potential to address security concerns and other complexities encountered by healthcare industries when electronically documenting, storing, and recovering patient data.

Globally, despite blockchain technology's advantages, there is a lack of adoption of this technology (13). This slow acceptance can be attributed to several factors, including a limited recognition of its potential value, the healthcare institutions' hesitation to embrace it, and organizations' readiness for its implementation (12).

In the domain of this study, there has been a noticeable absence of research examining the factors that influence the adoption of blockchain technology in Saudi healthcare data management. Therefore, it is vital to investigate these factors to provide insights that can assist decision makers in tailoring policies for the effective and acceptable integration of blockchains into the healthcare system. This understanding is crucial for promoting the meaningful use of blockchain technology and facilitating its successful implementation in Saudi Arabia.

1.2 Research Questions

The purpose of the following questions is to provide comprehensive insights into the integration of blockchain technology in Saudi healthcare data management:

1. What are the technical, organizational, and environmental attributes that affect the acceptance of the integration of blockchain technology in healthcare data management?

2. What are the factors that affect the acceptance of the integration of blockchain technology in Saudi healthcare data management from the viewpoint of healthcare organizations' employees?
3. What other healthcare services can benefit from the features of blockchain technology from the viewpoint of healthcare organizations' employees?
4. What recommendations can support decision makers in integrating blockchain technology into Saudi healthcare data management?

1.3 Research Objectives

The following research objectives are meant to fill in critical knowledge gaps regarding blockchain technology adoption in Saudi healthcare data management:

- To investigate the technical, organizational, and environmental factors that affect the adoption of blockchain technology in healthcare data management.
- To develop a theoretical framework that can assist decision makers in measuring the readiness of Saudi healthcare organizations to adopt blockchain technology.
- To investigate the factors that affect the adoption of blockchain technology in Saudi healthcare data management from the viewpoint of healthcare organizations' employees.

The rest of the study is organized as follows: Chapter 2 briefly outlines healthcare data management privacy and security threats, an overview of the Saudi healthcare data management system, and the background on blockchain technology. Chapter 3 discusses blockchain technology in healthcare and provides some examples of using blockchain technology in healthcare data management. Chapter 4 focuses on the development of the hypothesis and theoretical research framework. Chapter 5 describes the research methodology and discussion of the results. Chapter 6 presents the conclusion and future work

Chapter 2

Background

2.1 Overview

This chapter provides comprehensive details regarding the terminology used and the technology examined in the study to establish the foundation for the subsequent study. It comprises four sections: Section 2.2 defines healthcare data management, Section 2.3 addresses healthcare data management privacy and security threats, Section 2.4 provides an overview of the healthcare systems in the Kingdom of Saudi Arabia, and Section 2.5 contributes background information on blockchain technology.

2.2 Healthcare Data Management

Healthcare data management involves the comprehensive administration of medical data as a valuable asset, encompassing activities such as the acquisition, entry, processing, coding, outputting, retrieval, and storage of data collected in diverse healthcare domains (14). The concept of healthcare data management has evolved significantly over the past century, progressing from paper charts to EMRs. This evolution has brought about disruptive changes while aiming to enhance the accuracy of medical data. Furthermore, advancements in healthcare data management facilitate improved mechanisms for sharing medical data, a crucial necessity given the distribution of patient treatment across multiple healthcare providers (15). Sharing medical data among healthcare stakeholders can deliver multifaceted advantages beyond patient-centric benefits (16). Notably, these advantages encompass advancements in medical research, the formulation of health policies, improved medical diagnostics for certain conditions, and cost-effectiveness.

However, it is imperative to underscore that healthcare data sharing must be executed within a secure and safeguarded environment. It has been asserted that instances of data exchange incidents can reduce patient trust in healthcare information exchange platforms, thus highlighting the importance of maintaining data integrity throughout the sharing process (17).

2.2.1 Healthcare Data Management Privacy and Security Threats

The integration of EMRs has notably improved healthcare data management; however, it has also brought forth significant privacy and security concerns when sharing health information digitally. Notably, data breaches represent a major threat in the healthcare sector. Recent data from the Office of Information Security indicate that the frequency of healthcare data breaches has doubled over the past three years, affecting approximately 700 U.S. healthcare organizations in 2022 (18).

A healthcare data breach involves the unauthorized use or disclosure of protected medical data, and its implications are severe. These data are highly attractive to malicious actors due to the enduring value of the sensitive information they contain. Such information can be exploited for various illegal activities, such as engaging in identity theft, committing insurance fraud, and creating counterfeit prescriptions.

The causes of data breaches in healthcare are diverse, ranging from IT-related incidents and unauthorized access to improper record disposal. Moreover, the utilization of third-party software and lack of awareness introduce vulnerabilities that can contribute to breaches, as identified by the U.S. Department of Health and Human Services (19). Table 2.1 highlights both the causes of data breaches and vulnerabilities within the healthcare system.

Threat	Causes	Vulnerabilities
Data breach	IT-related incidents	1- Reliance on commercial software requiring frequent patching. 2- Vulnerabilities within medical network devices.
	Unauthorized entry	1- Unauthorized employees or stakeholders. 2- Sharing login credentials.
	Inadequate disposal practice	Failure to follow HIPAA-mandated disposal methods.
	Utilizing third-party software	Using third-party software not designed for healthcare systems for medical record exchange.
	Lack of awareness	Insufficient training and comprehension of security and privacy protocols among healthcare professionals.

Table 2.1: Causes of data breaches and vulnerabilities within the healthcare system.

- **IT-Related Incidents**

The widespread integration of EMR systems into healthcare has generated an escalating demand for easily accessible EMR solutions among healthcare providers. In response, healthcare providers increasingly employ commercial software. However, relying on commercial software exposes EMR systems to potential harm, especially in the event of security breaches. Commercial software regularly undergoes updates and patches to address emerging security threats (20). While individuals and enterprises can install these updates immediately, the healthcare sector faces a distinctive challenge in this regard. It must undergo a comprehensive Food and Drug Administration (FDA) review process before recommending updates to ensure they do not compromise the functionality and safety of the EMRs (21). Consequently, the use of commercial software in the context of EMR often leads to a delay in implementing crucial security updates, thereby creating a notable security gap and heightening vulnerability to potential security threats.

The rise of networked medical devices and equipment has significant security implications, notably when these devices lack security protection. Malware can be introduced into healthcare systems through various sources, encompassing desktops, laptops, and smartphones within the same network, causing a complete shutdown of a hospital's operating system. For instance, viruses have the potential to compromise data integrity, leading to data deletion or misplacement (22). This disruption may impede physicians' access to critical patient information, thereby interfering with the efficient delivery of healthcare services.

- **Unauthorized Entry**

Unauthorized access to patients' medical data is a significant concern in healthcare. This issue extends to various stakeholders and employees who can inadvertently or intentionally access such records, thus posing a risk to patient privacy and data security. For instance, a case in which a former employee of Memorial Hermann Hospital in the United States accessed over 10,000 EMRs without authorization underscores the gravity of this problem (23). Additionally, there is a notable lack of awareness among healthcare employees about the risks associated with sharing login credentials. For example, healthcare staff sometimes share passwords with medical students to access medical records, potentially due to a lack of appreciation of the potential consequences of data breaches (24),(25).

- **Inadequate Disposal Practice**

Inadequate disposal practices in healthcare pose a serious risk to patient data security. Some entities, such as healthcare providers, may overlook the necessary procedures for disposing of EMRs and associated hardware media despite their obligations under the Health Insurance Portability and Accountability Act (HIPAA). The HIPAA mandates the use of specific disposal methods, such as destruction, decomposition, or shredding, to guarantee the complete destruction of sensitive health information before any media is reused or discarded (26). This safeguards patient privacy and data integrity.

- **Utilizing Third-Party Software**

The use of third-party software for exchanging EMRs, especially when it is not designed for healthcare systems, presents significant security challenges, particularly the increased risk of data breaches, thus posing a threat to the security and confidentiality of healthcare information. For instance, certain text message applications, such as WhatsApp, are vulnerable to exploitation. These applications routinely archive text messages for extended periods, typically five years or more. Malicious actors may exploit these vulnerabilities for data mining purposes, potentially gaining access to sensitive and confidential information (27).

- **The Lack of Awareness**

Insufficient awareness and comprehension of security and privacy protocols among healthcare professionals pose a significant risk to the security of medical data. The lack of training and awareness regarding privacy and security healthcare policy can lead to an undervaluation of the potential severity of confidentiality breaches (25), (28). In a prior study, it was observed that most medical staff and employees opted to use their phones to save and transfer clinical reports via messages or email (29), even though most of the surgeons had been trained in HIPAA compliance and were knowledgeable about electronic communication regulations (30). A potential motivating factor for medical staff and employees engaging in such practices could be the convenience of using their phones (31).

Therefore, regulatory guidance and increased awareness are important to assist physicians in making informed decisions about the appropriate use of mobile messaging for medical communications to reduce risk (28).

Hence, it is necessary to leverage sophisticated technology that can offer robust security measures, ensuring that only authorized personnel can access healthcare data. Furthermore, patients should be informed about the intended use of their data and should actively participate in the process.

2.3 Overview of the Healthcare Systems in the Kingdom of Saudi Arabia

Until a few decades ago, healthcare data management in the Kingdom of Saudi Arabia (KSA) relied on paper-based medical records. In 2008, the Ministry of Health (MOH), on behalf of the Saudi Arabian government, recognized the importance of advancing the system to an electronic one. A major part of this strategic plan was to switch from paper-based records to EMRs. The main goal of this project was to create a secure, high-quality healthcare system with a patient-focused strategy. This project was improved using cutting-edge technology (32). However, Saudi Arabia's healthcare facilities have made limited progress in implementing EMRs. A survey of 15 hospitals in the Eastern Province of Saudi Arabia revealed that only seven (constituting 46.6% of the total) had successfully implemented EMR systems (33). The barriers that limit the widespread adoption of EMRs are the possible loss of data in the event of power failures or computer crashes, the threat of security breaches, the complexity of the technology to staff with limited computer ability, and the significant time and effort required for data input and quality assurance (33).

In 2015, as part of the 2030 Saudi Vision, the MOH initiated the Healthcare Sector Transformation Program, with the aim of enhancing the Kingdom's healthcare system, making it more efficient and seamlessly integrated. Among its objectives was the evolution of digital health services (34). Nevertheless, while the Healthcare Sector Transformation Program formulated a robust strategy for digital health transformation, it faces barriers associated with the information technology (IT) infrastructure of healthcare providers (35). One of these obstacles relates to the limited interoperability of EMR systems, which complicates the exchange of medical information among healthcare providers. This lack of interoperability negatively impacts the patient experience and contributes to increased cost expenditures. For instance, when patients seek care at new hospitals, they are often required to recount their medical histories or undergo redundant medical assessments due to the fragmentation of their EMRs across different healthcare facilities (36). Furthermore, the presence of independent EMR systems within the same hospital poses an additional challenge. Each department within the healthcare institution operates on its own server and maintains a separate database to store patients' medical data. For example, data from the clinical laboratory department are restricted to its independent database within its respective servers. This approach adheres to a single responsibility principle whereby all relevant data must be segregated into autonomous databases hosted on separate servers (36).

The MOH collaborates with various organizations across the country to address challenges within the healthcare system. In 2023, the National Platform for Health and Insurance Exchange Services (NPHIES) was introduced. This platform serves as a centralized hub for sharing information among healthcare facilities and relevant stakeholders. Importantly, it allows for the creation of comprehensive healthcare records that encompass the entire medical history of patients (37). Figure 2.1 illustrates the Saudi healthcare system before and after the NPHIES .

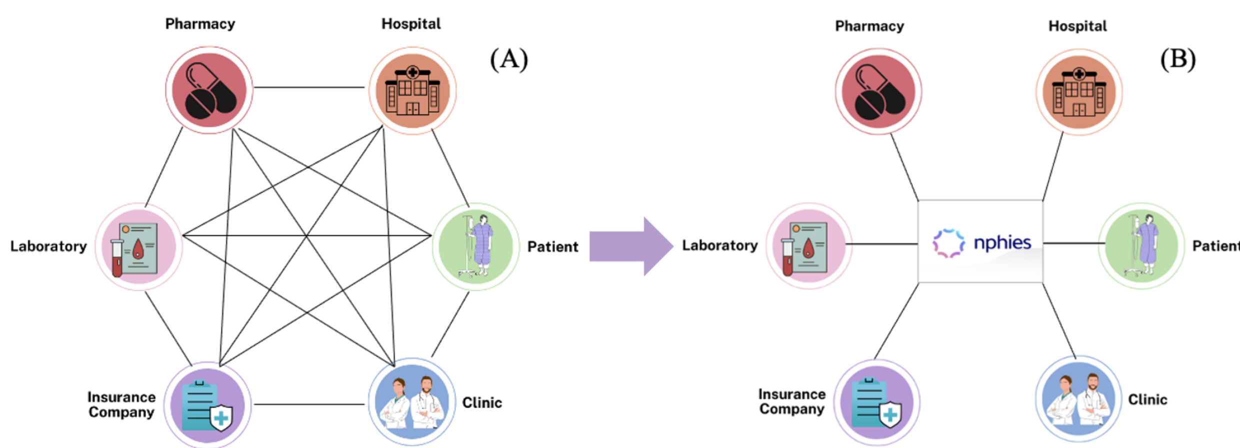

Figure 2.1: A) Healthcare system before the NPIES, B) Healthcare system after the NPIES

The NPHIES is structured into two key components:

1- Insurance Services: This component facilitates the transfer of administrative and financial information between healthcare providers and insurance firms, resulting in enhanced services for beneficiaries. It expedites insurance approvals, improves the management of financial claims, and strengthens the detection of fraudulent activities (38).

2- Clinical Services: This component enables unified patient health records, which elevate the quality and efficiency of healthcare provision. In addition, they result in cost reductions and time savings by facilitating the effortless exchange of information (38).

The implementation of the NPHIES offers several benefits, including the enhancement of interoperability, increased precision in patient treatment, and reduced healthcare expenditures. This innovative platform is pivotal in transforming and optimizing the healthcare system in the KSA (39).

However, the NPHIES' role as a centralized hub for exchanging information makes it susceptible to specific security concerns. To clarify, data continue to reside within the autonomous databases of healthcare providers or stakeholders. In the event of a denial of service (DoS) attack targeting the platform, the entire system may experience disruption. Additionally, there is an increased probability of communication congestion within its singular data repository, given that numerous requestors may simultaneously engage with it (40). Significantly, patients lack complete authority over their data and remain unaware of any activities regarding their records, including instances in which their records are shared for research trials (41).

These challenges, in addition to concerns related to privacy and security, can be mitigated by integrating cutting-edge technologies, such as blockchain technology, which can potentially significantly transform the healthcare industry's operations.

2.4 Blockchain Technology Background

The blockchain represents a fraud-proof and tamper-proof digital ledger deployed in a decentralized manner without a central repository or authoritative entity, such as a financial institution, corporation, or government. In essence, it empowers a group of participants to document transactions in a shared ledger within that community. Importantly, within the standard operation of a blockchain network, once a transaction is published, it remains immutable and cannot be altered (9).

In 1991, blockchain technology was introduced, and its ability to record transactions securely in a ledger was demonstrated (42). In 2008, the blockchain concept was described in Satoshi Nakamoto's white paper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System" (43). The author discusses the protection of digital currency via cryptographic methods rather than a central authority. In 2009, Bitcoin was presented as the first blockchain application (9). Blockchain technology empowered Bitcoin to function as a decentralized system, eliminating the presence of a single user in control and the risk of a single point of failure. The principal advantage of Bitcoin is that it facilitates direct peer-to-peer transactions and eliminates the necessity of a trusted intermediary. Blockchains operate as decentralized digital ledgers encompassing transactions protected by cryptographic signatures and structured into blocks. Each block is cryptographically connected to the previous block, guaranteeing tamper resistance following validation and consensus. As new blocks are added, the resilience of older blocks against tampering grows, rendering them more challenging to modify. Subsequently, the blockchain ledger is distributed across various nodes to establish transparency among network users (9).

2.4.1 Blockchain Network Types

Blockchain is categorized into three distinct types based on accessibility, governance, and participant responsibility. Table 2.2 shows a comparative analysis of the three blockchain types.

- **Public Blockchain Network**

Public blockchains, also referred to as permissionless blockchain networks, are decentralized networks in which anyone can verify transactions and publish new blocks. While this openness offers transparency, it also exposes the system to potential misuse by malicious users who might attempt to disrupt it. To counteract this, public blockchains utilize consensus mechanisms, such as proof of work (9).

- **Private Blockchain Network**

Private blockchains, known as permissioned blockchain networks, are centralized networks wherein a central authority grants permission to users to publish a new block. Given that all block creators are authorized, consensus protocols are less resource intensive and result in faster transaction processing (9).

- **Federated Blockchain Network**

Federated blockchains, also called permissioned blockchain networks, operate as semi-decentralized networks in which a predetermined group of participants collectively authenticate transactions (44).

Blockchain Type	**Accessibility**	**Governance**	**Participant Responsibility**
Public	Open to anyone	Decentralized	Anyone can verify and publish transactions.
Private	Restricted access	Centralized	Only authorized users can verify and publish transactions.
Federated	Restricted access	Semi-decentralized	Only predetermined participants can verify and publish transactions.

Table 2.2: A comparative analysis of the three blockchain types.

2.4.2 Main Concepts of Blockchain Technology

- **Block Structure**

A block is divided into two key components:

1. The block header encompasses the block number, the hash of the data block, the hash

of the preceding block, a timestamp, and the block's size. (9).

2. Block data contain a collection of verified transactions and additional data (9).

- **Ledgers**

Blockchain ledgers are digital records of transactions distributed in nature and managed by a decentralized ownership structure (9).

- **Chaining Process**

To establish the blockchain, each block must possess the hash digest of the previous block's header, a process known as the chaining process. Thus, identifying and rejecting modified blocks is straightforward, as they have different hash digests (9). Figure 2.2 illustrates the chaining process.

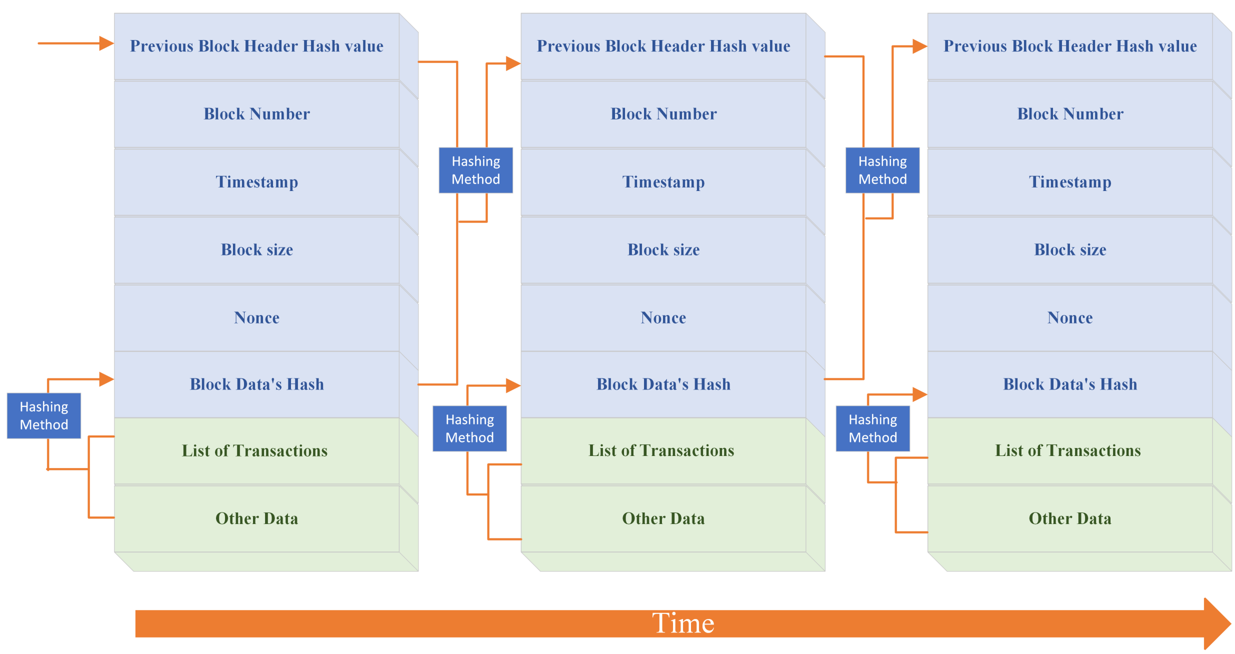

Figure 2.2: The chaining process.

- **Transactions**

Transactions symbolize communication between miners within the blockchain network. The transaction process is the same across various blockchain implementations. In a blockchain network, a miner initiates a transaction that is accompanied by the sender's digital signature, which represents the sender's private key. Subsequently, this transaction is broadcast to nodes within the network. Miners employ algorithms to assess and authenticate the proposed transaction. If an agreement is reached among most of the network miners regarding the transaction's validity, it is appended to a shared block. This block is then assigned a hash value to be chained to the blockchain (9). Figure 2.3 illustrates the execution of a transaction.

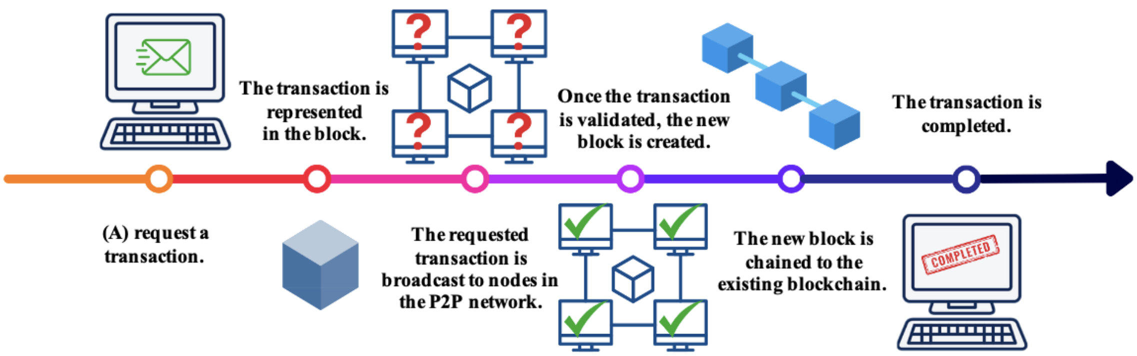

Figure 2.3: The execution of a transaction.

- **Consensus Mechanisms**

Consensus methods determine which participant in the blockchain network is responsible for creating the next block. Various consensus mechanisms, such as proof of work, proof of stake, round robin, proof of identity, and proof of elapsed time, can be utilized. These mechanisms are designed to facilitate cooperation among potentially untrusting users in blockchain networks (9).

- **Smart Contract**

Smart contracts are predefined conditions encoded and integrated on top of the blockchain framework. Upon satisfying these conditions, transactions are automatically initiated (45).

Smart contracts within the healthcare domain are pivotal in regulating access control. They offer a mechanism for individuals to specify their preferences regarding the use of their personal health data, particularly for designated research purposes (46).

2.4.3 Blockchain Technology Characteristics

• **Decentralization** within the blockchain context involves shifting control and decision-making authority from a centralized entity, whether an individual or organization, to a distributed network. Consensus algorithms, such as proof of stake or proof of work, are frequently used for transaction validation in this paradigm. This structural approach contributes to elevated security, transparency, and resilience, thus mitigating the risks associated with a single point of failure (10).

• **Immutability** refers to the inability of miners to alter recorded transactions once they have been added to the shared ledger. In the event of an error within a transaction record, miners must append a new transaction to fix the mistake, and both transactions remain visible to the network (10).

• **Auditability** in a blockchain denotes the capability to observe and authenticate a transaction within a decentralized ledger, providing users with confidence in the accuracy and legitimacy of the data. Furthermore, even historical records within blockchains remain accessible (10).

• **Anonymity** in blockchain technology refers to the ability of each user to engage with a blockchain using a generated address, thereby concealing their true identity (10).

• **Persistency** in blockchain technology implies the quick validation of transactions, with miners rejecting invalid transactions. Once included in a blockchain, the deletion or rollback of transactions becomes highly challenging. The quick identification of blocks containing invalid transactions is important within this framework (10).

Chapter 3

Related Work

3.1 Overview

This chapter provides comprehensive information on utilizing blockchain technology in healthcare data management. It comprises four sections: Section 3.2 introduces blockchain technology used in healthcare; Section 3.3 presents healthcare data management requirements aligning with blockchain features; Section 3.4 covers blockchain technology adoption in healthcare data management; and Section 3.5 examines blockchain technology adoption specifically in Saudi healthcare data management.

3.2 Blockchain Technology in Healthcare

The healthcare sector can benefit from integrating blockchain technology into various aspects of the healthcare system, owing to its attributes of accessibility and security. For example, the application of blockchains in the pharmaceutical industry plays a pivotal role in preventing the proliferation of counterfeit medicines (47). Furthermore, blockchain technology aims to enhance medical data management and streamline insurance claim processes, simultaneously expediting biomedical and clinical research progress (48). Blockchains empower patients to own and manage their data without compromising data security or impeding the sharing of healthcare services (49). In addition, blockchains promote rapid and simplified interoperability between systems and can be expanded effectively to deal with increased data volumes (50).

3.3 Healthcare Data Management Requirements Aligned With Blockchain Features

Blockchain technology offers diverse attributes that can be effectively harnessed within the healthcare sector to meet its specific requirements, encompassing aspects such as ensuring interoperability, safeguarding data integrity, and facilitating secure data exchange. Figure 3.1 summarizes healthcare data management requirements aligned with blockchain features.

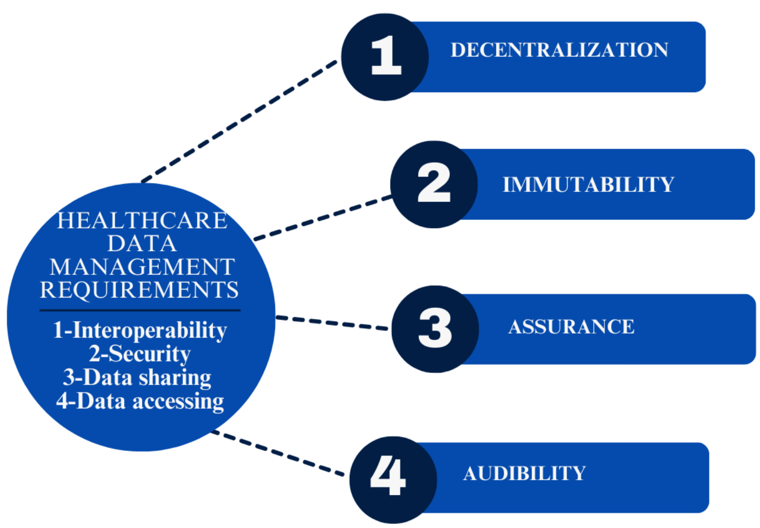

Figure 3.1: Healthcare data management requirements aligned with blockchain features.

- **Interoperability**

Interoperability refers to a system's ability to exchange and transfer data among disparate sources without constraints. The predominant obstacle to achieving interoperability is that most healthcare data management systems depend on medical technologies, technical requirements, and operational capabilities. These differences pose challenges in electronically sharing medical data, even within the same platform. However, integrating blockchain technology into the healthcare data management system offers a promising solution to interoperability issues since medical data stored on the blockchain system pursue a standardized data code. Hence, any healthcare institution can easily access and use the medical data (51).

- **Data Security**

In the transition of medical data from paper to digital formats, it is important to implement strengthened security measures and role-based access privileges to safeguard medical data and ensure its integrity.

By harnessing the power of a blockchain system's decentralized storage, blockchain technology enhances security through the distribution of medical data across multiple computer nodes instead of relying on a single server (52),(53),(54). This decentralized ledger approach facilitates the propagation of transactions throughout the entire blockchain network, creating numerous duplicative data sources (52),(53),(54). The redundancy inherent in this architecture prevents malicious actors from altering data without simultaneously affecting the information on all systems within the network. As a result, blockchains ensure immutability, which inspires assurance and maintains data integrity.

- **Data Sharing and Accessing**

Medical data are highly sensitive because they contain permanent personal and health information. Accessing and sharing medical data presents security concerns regarding data integrity, availability, and confidentiality. Thus, extensive protection mechanisms are required so that only authorized people can access this sensitive information and monitor any changes.

Consequently, integrating blockchain technology within healthcare data management provides a secure solution for data sharing, offering auditing mechanisms and data provenance. This is achieved by implementing smart contracts and access control measures, contributing to the robust security of healthcare data management and reducing the risk of medical data being altered or copied (55).

3.4 Blockchain Technology Adoption in Healthcare Data Management

Several blockchain applications have been utilized in healthcare data management, as illustrated in the following examples.

- **The Estonia's E-Health System**

Estonia marked the first instance of a nation-state leveraging blockchain technology within its healthcare system (56). In 2016, the Estonian government initiated a project utilizing blockchain technology to enhance the security of health records and system access for its 1.3 million residents. This project, established in collaboration with Guardtime, a Netherlands-based data security firm, links citizens' electronic health record data with their blockchain-based identities. It has an advanced electronic healthcare record system whereby each person who has visited a doctor possesses an online record accessible through an electronic ID card. Therefore, any change in a patient's medical records will be hashed and registered in the blockchain, preventing malicious modifications to the records and maintaining an immutable audit trail of any updates. According to (56) by utilizing Estonian blockchain technology, data breaches can be promptly detected compared with today's average time taken to identify data breaches, which is seven months. Additionally, the system integrates data from various healthcare providers, allowing patients to access their standardized medical information through an electronic patient portal and enabling doctors to easily access and view patients' records (57). As elucidated by (58), more than 95% of data produced by hospitals and physicians has been converted into digital format, facilitating convenient access to patients' electronic records for doctors.

- **The MedRec Platform**

MedRec is one of the most widely recognized prototypes and early-stage blockchain technology solutions. It is a decentralized platform built on Ethereum blockchain technology that serves as a solution for managing EMRs. Its primary objective is to provide patients with access to their health records across various healthcare providers and to control who can access their records. This platform operates on a private blockchain, meaning that only authorized individuals can access the system. MedRec offers adaptability by seamlessly integrating with the local databases of both healthcare providers and patients. To facilitate and monitor transactions, MedRec employs three types of smart contracts. The Registrar Contract (RC) is a global contract responsible for linking a patient's identity with their unique Ethereum address. It also enforces policies governing new registrations and changes to existing records. The Patient–Provider Relationship Contract (PPR) is established between healthcare providers and patients, defining access permissions. Finally, the Summary Contract (SC) is employed to help patients and providers maintain a record of their medical history and interactions with others. An essential feature of MedRec is its automated notification system, which alerts healthcare providers and patients to new information. This notification allows them to verify the information before deciding to accept or reject it (59).

- **The Medicalchain Open-source Platform**

Medicalchain, a decentralized open-source platform based in the UK, facilitates the storage and exchange of medical data. It aims to create user-centric electronic health records, maintain a unified health file, and allow patients to control their medical records. The blockchain serves as a pointer to patient data location in an encrypted format, making it significantly more challenging for anyone trying to intercept it. Running on the permission-based Hyperledger Fabric architecture, it enables flexible access control, empowering patients to manage who, how much, and for how long their records are viewed. Furthermore, the platform offers patients a comprehensive log detailing access to their medical data, including identities, timestamps, and the specific data accessed (60).

- **The MediBloc Open-source Platform**

MediBloc, a South Korea-based open-source healthcare data platform operating on blockchain technology, facilitates the secure integration and management of medical data fragmented between diverse healthcare providers and devices, including smart devices. Patients have comprehensive access to their data. Moreover, they can determine access permissions for healthcare providers to make changes to their records. The platform mainly manages three categories of information: medical balance, personal data, and healthcare records. All data, such as medical and personal information, are encrypted and stored off-chain, and only the hash value of these data is assigned on-chain to overcome constraints related to cost, performance, and storage capacity (61).

3.5 Blockchain Technology Adoption in Saudi Healthcare Data Management

There is a noticeable absence of evidence regarding the adoption of blockchain technology in Middle Eastern healthcare, particularly in Saudi Arabia. Therefore, assessing the potential acceptance of new systems is imperative before integrating a novel technology. This is because the value of highly advanced and innovative solutions diminishes significantly when consumers fail to adopt them. Additionally, ensuring compatibility with existing systems is essential for successfully implementing new technology (62).

Therefore, it is essential to identify the factors influencing the adoption process to measure the likelihood of an organization adopting a ground-breaking technology such as blockchain. Several models and theories in the information systems (IS) field assist in identifying the factors that can have a substantial or negligible influence on utilizing IT innovations in organizational contexts. The next chapter systematically reviews the existing literature to identify the factors that have demonstrated the most substantial impact on the adoption of blockchain technology.

Chapter 4

Hypothesis Development and Theoretical Research Framework

4.1 Overview

This chapter provides a theoretical foundation and a research framework for the study. A systematic review was conducted to identify the factors that affect blockchain technology adoption, which were then used to construct the theoretical study framework. This chapter comprises three sections: Section 4.2 provides an overview of the technology adoption theory used; Section 4.3 is a systematic literature review of the factors affecting blockchain technology adoption; and Section 4.4 contributes to the hypothesis development and proposed theoretical research framework.

4.2 Overview of the Technology Adoption Theory Used

Deciding on the theoretical method employed to construct the research hypotheses and framework is critical for guiding the investigation. Various technology adoption theories, such as the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT), can be used to examine the adoption of any new IT innovation. However, these theories were found to be unsuitable in relation to blockchain adoption. This is because they concentrate on individual-level adoption and overlook the organizational perspective (33). In contrast, blockchain technology significantly impacts the organizational level, making these individual-centric theories inappropriate. Therefore, it is essential to utilize a theory capable of determining the internal and external factors that may affect an organization.

A previous study on adopting innovative information technology (63), put forward a framework comprising the technological, organizational, and environmental dimensions (TOE) that influence the adoption and implementation of technological innovations at the organizational level. The technological dimension involves the features of the technology itself that affect its adoption procedure. The organizational dimension explores how an organization's characteristics and resources affect decisions related to the adoption of innovations. Concurrently, the environmental dimension refers to the impact of the outer and interfirm environments within which the organization works. Understanding these three aspects assists the researcher in comprehending the opportunities and challenges associated with adopting new IT innovations (63).

The TOE framework has gained widespread acceptance and has been applied in various studies on the adoption of blockchains or IT. For example, one study investigated the factors impacting the integration of cloud computing in the Jordanian EMR system by employing the TOE framework (64). Similarly, another study examined the adoption of cloud computing in Sri Lanka's healthcare sector using the TOE framework (65).

Therefore, it can be asserted that the TOE framework is the most validated theory for examining the factors affecting the potential adoption of blockchain technology in healthcare data management in the KSA.

4.3 Systematic Literature Review of Factors Affecting Blockchain Technology Adoption

In this study, systematic reviews aim to identify, assess, and summarize the outcomes of relevant individual studies related to the adoption of blockchain technology. These reviews enhance decision makers' accessibility to existing evidence. Additionally, they highlight gaps in the current literature and provide valuable insights into the direction of future research initiatives (16). Such reviews are divided into five phases: the database search, criteria for inclusion, selection process, search result, and identification of influential factors.

4.3.1 Database Search

This systematic literature review utilized the Scopus database for data collection. A comprehensive database search was performed with the search queries "blockchain" AND "accept*" OR "adopt*" resulting in the identification of 7,874 studies during the initial search phase.

4.3.2 Criteria for Inclusion

When identifying relevant articles to address the research inquiries, an assessment was conducted according to the following criteria:

- Scope: The date range chosen for consideration was from 2017 to 2023.
- Data Sources: Only conference papers, book chapters, reviews, and conference reviews were chosen for inclusion in the data analysis.
- Language: The systematic literature review included only sources in the English language.

4.3.3 Selection Process

The subsequent improvement and selection of the results were conducted in the following phases:

- Initial filtering was performed based on data sources containing the keywords ("health*" OR "medical*").
- Subsequent filtering was performed based on the framework to be employed in this study using the keywords ("TOE" OR "toe" OR "toe-frame*").

4.3.4 Search Result

In defining our research parameters, we opted to use the literature from 2008 to 2023. However, an examination of the Scopus database revealed that publications on blockchain applications only started to appear in 2016, as illustrated in Figure 4.1. Consequently, the number of publications spanning 2017 to 2023 amounted to 7,807. This was reduced to 4,066 studies based on including specific data sources and language filtration.

From the pool of 4,066 publications, we sharpened our focus by employing the query ("health*" OR "medical*"). This query was specifically aimed at relevant studies addressing factors affecting the adoption of blockchain technology within the healthcare organization, thus aligning with the scope of our research, which resulted in 600 studies.

Further improvement, guided by the TOE framework chosen, involved employing the query ("TOE" OR "toe" OR "toe-frame*"), narrowing our focus to seven studies.

These outcomes were organized using Mendeley reference software, which included the removal of duplicate entries. The subsequent examination of the titles and abstracts led to three studies being retained.

As a result, we broadened our search to encompass sectors beyond healthcare. In this phase, we omitted the health-related query ("health*" OR "medical*") and introduced a new query ("factor*" OR "influence*" OR "determinant*"), yielding 25 studies.

Prioritizing quality assurance, we subjected the studies to a strict evaluation based on specific criteria:

- Does the study investigate factors influencing the adoption of blockchain technology using the TOE framework?
- Does the study validate the TOE framework in real-world contexts?
- Are the results precise and aligned with the study's hypotheses?

Following this evaluation, 16 studies met the outlined quality criteria. Subsequently, each paper was analyzed in its entirety to extract and comprehend the factors affecting the adoption of blockchain technology.

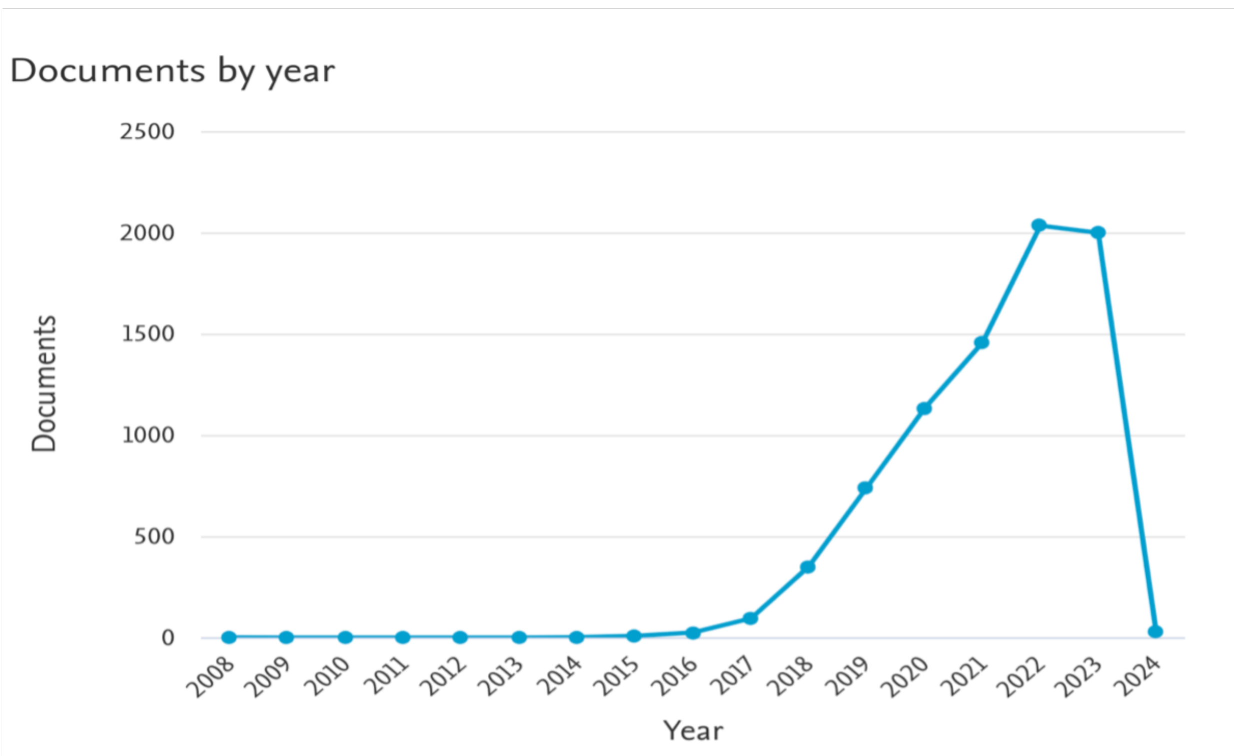

Figure 4.1: Blockchain publications over the years.

4.3.5 Identification of Influential Factors

Following a detailed data analysis and validation process, 34 factors emerged as significant contributors to the adoption of blockchain technology, as shown in Figure 4.2. These factors were systematically extracted from the empirical studies.

To arrive at a definite conclusion regarding the influence of a determinant, two defined requirements must be met:

1. Agreement in most studies regarding its positive or negative impact.

2. Investigation of the factor in a minimum of five research studies.

A frequency analysis conducted within the studies exploring blockchain adoption revealed six indicators, which were categorically grouped into three factors:

- Technological factors, encompassing relative advantage and complexity.

- Organizational factors, including leadership support and healthcare provider readiness.

- Environmental factors, encompassing government support and competitive pressure.

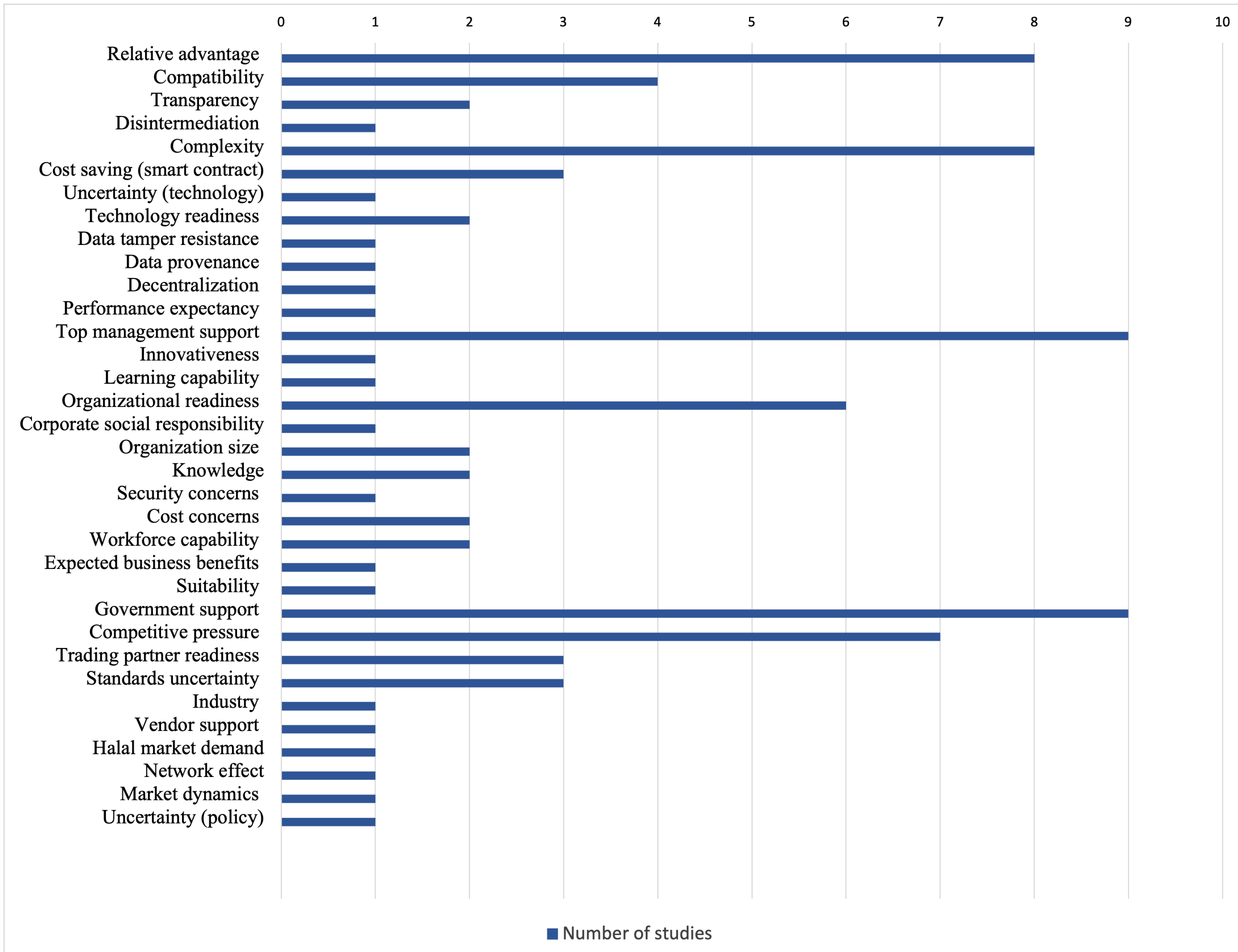

Figure 4.2: Extracted factors based on previous studies.

4.4 Hypothesis Development and Theoretical Research Framework

In developing the research hypothesis phase, the most significant factors influencing the adoption of blockchain technology across diverse sectors were identified from existing studies and classified based on the TOE framework. Subsequently, each framework context—technological, organizational, and environmental—is clarified. Ultimately, the theoretical research framework is outlined.

4.4.1 Hypothesis Development

4.4.1.1 Technological Factors

The technological dimension explains the features encompassing the equipment, functionalities, methods, and costs that shape the adoption process (63). In this study, diverse technological factors, namely relative advantage and complexity, may influence the adoption of blockchain technology in Saudi healthcare data management.

- **Relative Advantage**

Relative advantage refers to the degree to which businesses perceive innovation as advantageous to their operations (66). The greater the advantages of incorporating blockchain technology into healthcare sectors, including security, interoperability, immutability, and auditability, the higher the likelihood of the sectors embracing this innovative solution (13). Numerous studies have emphasized the importance of relative advantage in accelerating the adoption of blockchain technology in different sectors. The relative advantage of blockchain technology encourages its adoption within the elderly healthcare sector, as stakeholders assert that the technology offers enhanced safety and reliability compared to current systems (6). Within accounting applications, the attributes of blockchain technology, notably its immutable ledger, render it an optimal choice for an accounting system compared to the existing systems in use (67). The research findings indicate that relative advantage positively impacts the preference of Indian small and medium enterprises (SMEs) to embrace blockchain technology within their supply chains, wherein the relative advantages encompass transaction tracking, transparency, and data availability with precise time stamping (68). The most significant factor impacting the adoption of blockchains within financial sectors is its relative advantage in relation to the secure nature of its cryptographic algorithms and consensus protocols, which safeguard data integrity and deter malicious alterations (69).

- **Complexity**

Complexity denotes the extent to which blockchains are relatively challenging to embrace and utilize (70). Typically, increased complexity leads to user confusion and difficulties comprehending and employing the technology, thereby negatively influencing the decision to adopt it (71). Consequently, new technologies must prioritize user friendliness to enhance their adoption rates. Research conducted in Australia indicates that organizations perceive blockchain technology as challenging to use and comprehend; hence, the complexity of this technology negatively influences Australian organizations' decisions to adopt it (72). In the supply chain sector, consumers have expressed initial concerns about the complexity of acquiring the necessary skills for engaging with blockchain technology, which plays a significant and negative role in influencing SMEs' adoption of blockchain technology in India (68). Research conducted in Ireland has revealed that the rejection of blockchain technology by both large organizations and SMEs derives from the high levels of complexity and the absence of applicable business use cases. This includes the complexities inherent in a substantial digital transformation, notably the transition from traditional centralized systems to decentralized ones (13). In the Malaysian supply chain context, a notable barrier to adoption has been revealed as complexity that encompasses the challenges related to system functionality, process efficiency, and utilization (71).

Conversely, a study within the elderly healthcare sector revealed that complexity does not have a noticeable impact on the adoption of blockchains. Instead, the organization in the study perceived that the various benefits offered by blockchain technology outweigh the challenges, leading to the belief that the complexity associated with blockchain adoption can be overcome (6).

4.4.1.2 Organizational Factors

The organizational context refers to the impact of an organization's characteristics and resources, such as its management structure and size, on decisions related to innovation adoption (63). This study anticipates that the key factors influencing the adoption of blockchain technology in healthcare data management in Saudi Arabia will include healthcare providers' readiness and support from leadership.

- **Healthcare Providers' Readiness**

Organizational readiness is characterized by the presence of the necessary resources within the organization for successful adoption. This encompasses the need for a technical infrastructure capable of supporting the latest IT inventions, specialized human resources possessing the requisite IT familiarity and skills, and financial resources allocated to implementing such inventions (73),(74). Numerous studies have emphasized the importance of organizational readiness in accelerating the adoption of blockchain technology in different sectors. For example, a study conducted in Ireland demonstrated that adequate organizational readiness, encompassing access to IT infrastructure, skilled employees, and the availability of financial resources, positively impacts the decision to adopt blockchain technology for both large enterprises and SMEs (13). Within the financial domain, organizational readiness, including factors such as the organization's size and financial robustness, plays a critical role in shaping the adoption of blockchains, wherein financial stability is crucial owing to the substantial initial investments required (69). The organization's size, measured by data volume, transaction frequency, and network complexity, underscores the necessity of blockchain adoption, which is particularly relevant for firms requiring the digitization of large data volumes for collaborative sharing (69). In addition, an organization's readiness has been shown to positively influence the incorporation of blockchain technology within the Malaysian halal food supply chain, thus enhancing overall business performance (75).

- **Leadership Support**

Leadership support emerges as a pivotal and frequently repeated factor in IT innovation adoption within a firm. Adopting blockchain technology entails navigating new regulatory demands, managing significant complexity, integrating existing resources, acquiring additional resources, and cultivating new competencies and skills. Consequently, securing acceptance and support from organizational leadership is imperative in this multifaceted process (13). Research on the integration of blockchain technology in Australian organizations has revealed that the support of top management is significant due to its authoritative role in approving strategic decisions, including adopting new technology and allocating resources for such initiatives (72). Moreover, another research study indicated that upper management's requisite support is crucial to successfully integrate blockchain technology into accounting systems (67). Within the Malaysian supply chain, upper management typically has the authority to determine investments in new technology. Consequently, if the leadership possesses an enhanced understanding of blockchain technology, it is more willing to foster a positive adoption intention and fund its implementation (71). In the context of Indian SMEs, implementing blockchain technology is perceived as potentially expensive. This cost perception may hinder technology adoption if top management does not allocate adequate resources. Therefore, the study findings emphasize that a favorable perspective from top management will likely encourage SMEs' adoption of blockchain technology (68).

4.4.1.3 Environmental Factors

The environmental context outlines the impact of the external and interenterprise environments within which a business operates (63). External elements, encompassing regulations, policies, and stakeholder cooperation, have the potential to either facilitate or hinder an organization's embrace of innovation (69). Within the framework of this study, the adoption of blockchain in healthcare data management in Saudi Arabia is expected to be influenced by two key factors: government support and competitive pressure.

- **Government Support**

The tendency of organizations to adopt emerging technologies is influenced by governmental support. Governmental support can manifest through various means, such as supporting technology initiatives, reinforcing digital infrastructure, and providing incentives to stimulate technology integration (76). For instance, the Australian government's implementation of support measures, such as developing regulations and policies, to facilitate the integration of blockchain technology has resulted in a high level of satisfaction expressed by Australian organizations regarding the support provided (72). The widespread suspicion and instances of prohibition regarding Bitcoins and cryptocurrencies in some countries underscore the significance of governmental support in implementing regulations that govern enterprises in adhering to specific technological standards (67). In Thailand's financial sector, the positive influence of government support on the adoption of blockchain technology is evident. Thailand stands as one of the early adopters, having passed legislation permitting the utilization of digital assets as a medium of exchange (69). In Saudi Arabia, there is potential governmental support for the adoption of blockchain technology in healthcare sectors, aligning with the country's aim to promote digital transformation, as outlined in its 2030 vision (77).

- **Competitive Pressure**

Competitive pressure denotes the level of stress experienced by an organization due to competition within the industry (78). The intensity of competition motivates organizations to explore strategies for growth and ways to maintain their competitive advantage. Blockchain solutions increase transparency and efficiency, thus delivering crucial competitive advantages to the food supply chain. This encourages firms to adopt blockchain technology within the food supply chain to maintain competitiveness in the market (79). A study on Malaysian SMEs found that the influence of competitive pressure on their intention to adopt blockchain technology was noteworthy. This suggests that SMEs are forced to stay pertinent and competitive in their business surroundings by adopting innovations (71). Moreover, competitive pressure has been found to have a crucial positive influence on leadership decisions to support the integration of blockchain technology within the elderly healthcare system (6).

4.4.2 Proposed Hypotheses

As a result of the above analysis, the adoption of blockchain technology in Saudi healthcare data management is anticipated to be affected by different factors, including technological, organizational, and environmental ones.

Hence, the following hypotheses can be formulated:

- **Hypothesis 1:** Technological factors positively affect the adoption of blockchain technology in Saudi healthcare data management.

- **Hypothesis 2:** Organizational factors positively affect the adoption of blockchain technology in Saudi healthcare data management.

- **Hypothesis 3:** Environmental factors positively affect the adoption of blockchain technology in Saudi healthcare data management.

The proposed theoretical research framework is shown in the following figure.

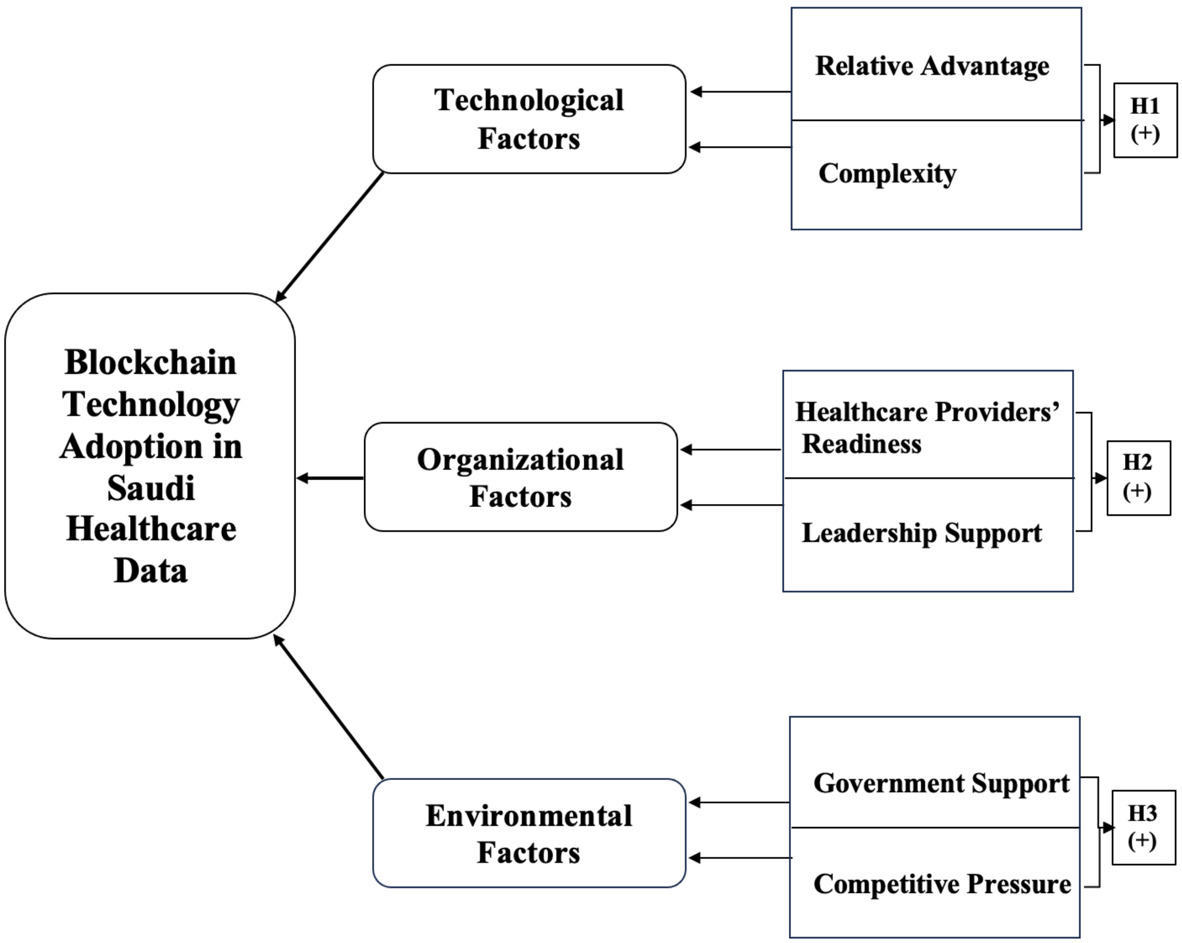

Figure 4.3: The proposed theoretical research framework for blockchain technology adoption in healthcare data management in the KSA.

Chapter 5

Methodology and Data Analysis

5.1 Overview

This chapter describes the methodology for this study, how the data will be collected, and which data analysis technique will be used to analyze the data to obtain the result. It also presents the results of the quantitative data gathered through an online survey. It is structured into five sections: Section 5.2 presents the research method, Section 5.3 describes the data collection process, Section 5.4 explains the data analysis technique, Section 5.5 shows the data analysis, and Section 5.6 discusses the findings gleaned from the study.

5.2 The Research Method

This research investigates the determinants influencing blockchain technology's integration into Saudi healthcare data management by employing a quantitative research methodology. The quantitative part of this study will mainly focus on analyzing the data derived from an online survey. An online survey is advantageous for gathering data from a broader population, enabling the measurement and testing of multiple variables and hypotheses (80). Additionally, this method is cost-and time-efficient (81).

To learn more about healthcare professionals' opinions on the possible integration of blockchain technology in healthcare data management, a survey will be distributed to those working in Saudi healthcare organizations. This specific group was selected because it can provide insightful information about the opportunities and difficulties of implementing a cutting-edge technology, such as blockchain, in the healthcare industry. Given their familiarity with daily workflows, healthcare professionals' input is essential for evaluating the seamless integration of blockchain technology into existing systems. Furthermore, understanding the attitudes of healthcare employees toward the adoption of new technologies is critical for successful implementation, and the survey aims to measure the level of acceptance or resistance among this demographic, thus assisting organizations in addressing potential obstacles.

5.3 Data Collection

An online survey was generated using the online platform Google Forms and distributed to participants through social media and email channels. The survey began with an informed consent section, providing participants with information about the research. Following the participants' agreement section, the survey comprised five sections, as detailed in Appendix B. Section One outlined the survey's purpose; Section Two focused on the participants' backgrounds; Section Three provided a brief description of blockchain technology and included questions about participants' proficiency in computing and understanding of blockchain technology; Section Four posed statements related to technological, organizational, and environmental factors, seeking participants' opinions; and Section Five requested suggestions on IT services suitable for migration to blockchain technology, along with participants' agreement on adopting blockchain technology in Saudi healthcare data management. The Likert scale, which is widely used to collect information on participants' ideas, viewpoints, and interpretations, was employed to measure the indicators of the study's framework. (82),(83).

Regarding sample size, it is essential to consider the chosen data analysis method before making a selection. This study decided on the partial least squares structural equation modeling (PLS-SEM) method to test the hypotheses and examine the research framework. Established guidelines recommend a sample size of at least ten times the number of indicators for PLS-SEM studies (84). With six indicators measuring three latent constructs, a minimum sample size of 60 was considered necessary to achieve the aim of this research.

Lastly, ethical approval was secured before data collection by submitting the necessary ethics form to the Research Involving Human Participants (IRB) at the Florida Institute of Technology. Approval was granted in February 2024 (NO. 24-009), as documented in Appendix A. The data collection process ensured confidentiality.

5.4 Data Analysis Technique

The analysis of the survey data will proceed through the following methods:

- **Descriptive Analysis**

Descriptive statistics will be employed to explain the fundamental characteristics of the research data. This facilitates a comprehensive understanding and summary of the data (85).

- **Partial Least Squares Structural Equation Modelling (PLS-SEM)**

PLS-SEM, a technique utilized for hypothesis testing, estimates path coefficients that denote the core relationships between indicators and latent constructs (86). The evaluation of path models through PLS-SEM encompasses two elements: the measurement model detailing relationships between latent constructs and associated indicators and the structural model outlining relationships between latent constructs (87). This study will perform PLS-SEM in two phases: the measurement model and the structural model. SmartPLS 4.0 software will be employed to execute this process.

5.5 Data Analysis

5.5.1 Descriptive Analysis

Descriptive analysis is the first step in statistical inquiry, which serves to articulate fundamental data characteristics within research endeavors (88). A survey was distributed among Saudi healthcare organizations. A total of 149 individuals engaged in the survey, with 129 responses considered valid. The demographic analysis outcomes are outlined in Section 5.1, encompassing variables such as educational level, professional status, and organizational type, as well as assessments of computer proficiency and familiarity with blockchain technology.

Demographic Information	**Frequency**	**Percent**
Educational level		
Diploma Certificate	6	4.7%
Undergraduate Degree	53	41.1%
Postgraduate Degree or Higher	70	54.3%
Professional status		
Administrative Staff	25	19.4%
Allied Health Professional (e.g., physiotherapist, pharmacist)	9	7.0%
Doctor/Physician	24	18.6%
Health Information Management Specialist	21	16.3%
IT Specialist	28	21.7%
Medical Student/Intern	4	3.1%
Nurse	11	8.5%
Other	7	5.4%
Organization type		
Government	67	51.9%
Semi-government	20	15.5%
Private	42	32.6%
Computer skills		
Basic	6	4.7%
Moderate	57	44.2%
Advanced	45	34.9%
Expert	21	16.3%
Understanding of blockchain technology		
None	76	58.9%
Basic	43	33.3%
Moderate	10	7.8%
Advanced	0	0%

Table 5.1: Demographic Information of participants.

5.5.2 Measurement Scale Analysis

Measurement scales were utilized to assess the impact of technological, organizational, and environmental factors on the adoption of blockchain technology in Saudi healthcare data management. The research employed the PLS-SEM technique to evaluate the hypotheses, estimating the path coefficients representing the core relationships among constructs (86), utilizing SmartPLS 4.0 software. Typically, the evaluation via PLS-SEM entails two primary components: measurement and structural models. The measurement model outlines the associations between constructs and their respective indicators, while the structural model explains the relationships among constructs (84). The outcomes of this analysis are elaborated on in subsequent subsections.

5.5.2.1 Measurement Model

The initial stage in employing PLS-SEM involves evaluating the measurement model. This aims to verify the reliability and validity of indicators within the construct, thereby confirming their suitability for inclusion in the model. Crucial criteria encompass indicator reliability, internal consistency reliability, convergent validity, and discriminant validity (89). Figure 5.1 shows the measurement model results.

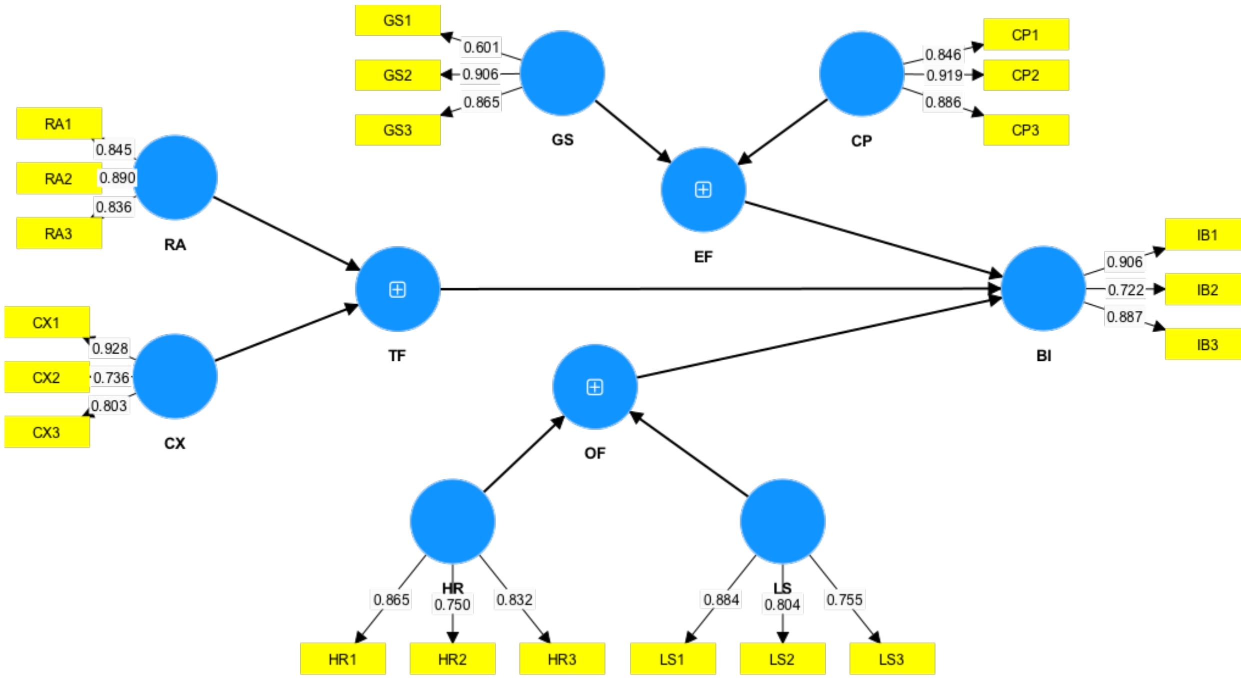

Figure 5.1: Measurement model.

- **Indicator Reliability**

The initial phase of assessing the reflective measurement model entails investigating the degree to which indicators are associated with latent constructs (84). When measuring reliability, higher values indicate higher reliability. An outer loading within the range of 0.60 to 0.70 is considered acceptable, while values falling between 0.70 and 0.95 are deemed reliable (90). The outcomes of this analysis are elaborated on in subsequent subsections.

1. Relative Advantage Analysis Results

Relative advantage refers to the degree to which businesses perceive innovation as advantageous to their operations (66). Table 5.2 shows the outer loading values of the three indicators, all exceeding 0.70 and falling within the range of 0.836 to 0.890. This suggests a reliable relationship between the indicators and their associated constructs.

Construct with Measuring Items	Outer loadings
Relative advantage (RV)	
RV1	0.845
RV2	0.890
RV3	0.836

Table 5.2: Indicator reliability for relative advantage

2. Complexity Analysis Results

Complexity denotes the extent to which blockchains are relatively challenging to embrace and utilize (70). Table 5.3 shows the outer loading values of the three indicators, all exceeding 0.70 and falling within the range of 0.736 and 0.928. This suggests a reliable relationship between the indicators and their associated constructs.

Construct with Measuring Items	Outer loadings
Complexity (CX)	
CX1	0.928
CX2	0.736
CX3	0.803

Table 5.3: Indicator reliability for complexity

3. Healthcare Providers' Readiness Analysis Results

Healthcare providers' readiness is characterized by the presence of necessary resources, such as IT infrastructure and human and financial resources within the organization, for successful adoption (73),(74). Table 5.4 displays the outer loading values of the three indicators, all exceeding 0.70 and falling within the range of 0.750 to 0.865. This suggests a reliable relationship between the indicators and their associated constructs.

Construct with Measuring Items	Outer loadings
Healthcare Providers' Readiness (HR)	
HR1	0.865
HR2	0.750
HR3	0.832

Table 5.4: Indicator reliability for healthcare providers' readiness

4. Leadership Support Analysis Results

Securing acceptance and support from organizational leadership is imperative because adopting blockchain technology entails navigating new regulatory demands, managing significant complexity, integrating existing resources, acquiring additional resources, and cultivating new competencies and skills (13). Table 5.5 shows the outer loading values of the three indicators, all exceeding 0.70 and falling within the range of 0.755 and 0.884. This suggests a reliable relationship between the indicators and their associated constructs.

Construct with Measuring Items	Outer loadings
Leadership Support (LS)	
LS1	0.884
LS2	0.804
LS3	0.755

Table 5.5: Indicator reliability for leadership support

5. Government Support Analysis Results

Governmental support can manifest through various means, such as supporting technology initiatives, reinforcing digital infrastructure, and providing incentives to stimulate technology integration (76). Table 5.6 displays the outer loading values for the two indicators (GS2, GS3), surpassing 0.70 and falling between 0.865 and 0.906, indicating a highly reliable relationship between these indicators and their respective constructs. Conversely, the relationship with GS1 is acceptable, with an outer loading of 0.601.

Construct with Measuring Items	Outer loadings
Government Support (GS)	
GS1	0.601
GS2	0.906
GS3	0.865

Table 5.6: Indicator reliability for government support

6. Competitive Pressure Analysis Result

Competitive pressure denotes the level of stress experienced by an organization due to competition within the industry (78). Table 5.7 displays the outer loading values of the three indicators, all exceeding 0.70 and falling within the range of 0.846 and 0.919. This suggests a reliable relationship between the indicators and their associated constructs.

Construct with Measuring Items	Outer loadings
Competitive Pressure (CP)	
CP1	0.846
CP2	0.919
CP3	0.886

Table 5.7: Indicator reliability for competitive pressure

Overall, the indicator reliability analysis results suggest a reliable relationship between the indicators and their associated construct.

- **Internal Consistency Reliability**

The second phase of assessing the reflective measurement model includes evaluating internal consistency reliability, which refers to the degree of association among indicators measuring the same construct (91). Composite reliability is a widely recognized measure of internal consistency reliability (89). In confirmatory studies, composite reliability should exceed 0.70, while in exploratory studies, it should be at least 0.60 (90). A value surpassing 0.95 suggests redundancy (90). Table 5.8 presents the composite reliability for each construct, ranging from 0.840 to 0.915. These values satisfy the criteria outlined in (90), indicating the measurement scales' high internal consistency and the reliability of the study instruments.

Constructs	Indicator Numbers	Composite Reliability	Comments
Relative advantage (RV)	3	0.893	High reliability
Complexity (CX)	3	0.865	High reliability
Healthcare providers' readiness (HR)	3	0.857	High reliability
Leadership support (LS)	3	0.856	High reliability
Government support (GS)	3	0.840	High reliability
Competitive pressure (CP)	3	0.915	High reliability

Table 5.8: Internal consistency reliability results

- **Convergent Validity**

The third step involves evaluating the convergent validity of each construct, which refers to the extent to which a construct effectively brings together its indicators to explain its shared variance (91). Convergent validity is assessed using the average variance extracted (AVE), which is calculated by summing the squared outer loadings of all indicators and dividing them by the number of indicators (91). An AVE value equal to or exceeding 0.50 indicates satisfactory convergent validity (91). The findings shown in Table 5.9 indicate AVE values ranging from 0.643 to 0.782 for the model constructs, demonstrating adequate convergent validity of the research model constructs.

Construct	Average Variance Extracted (AVE)
Relative advantage (RV)	0.735
Complexity (CX)	0.683
Healthcare providers' readiness (HR)	0.668
Leadership support (LS)	0.666
Government support (GS)	0.643
Competitive pressure (CP)	0.782

Table 5.9: Convergent validity results

- **Discriminant Validity**

The fourth step involves evaluating discriminant validity, which gauges how distinct a construct is from others in the structural model (91). Table 5.10 shows that the cross-loading values adhere to Fornell and Larcker's standards (92); each item within each construct exhibits higher loadings compared to the indicators of any other construct not aligned along the diagonal. Consequently, the proposed model achieved discriminant validity.

Construct	CP	CX	GS	HR	LS	RA
CP	**0.885**					
CX	-0.668	**0.826**				
GS	0.784	-0.54	**0.802**			
HR	0.513	-0.262	0.604	**0.817**		
LS	0.692	-0.401	0.756	0.705	**0.816**	
RA	0.344	-0.176	0.476	0.76	0.536	**0.857**

Competitive pressure (CP), Complexity (CX), Government support (GS), Healthcare providers' readiness (HR), Leadership support (LS), Relative advantage (RV)

Table 5.10: Discriminant validity results

In summary, the statistical outcomes of the measurement model surpassed the minimum acceptable thresholds. Thus, the proposed model attains the reliability and validity of the indicators within the construct.

5.5.2.2 Structural Model

Following the effective assessment of the measurement model in the preceding phase, the subsequent step involves examining the research hypotheses by assessing the structural model. The fundamental objective of the structural model is to investigate the interrelationships between constructs, often characterized as causal relationships, which encapsulate the theoretical framework connecting the constructs' significance and/or meaning (93). Figure 5.2 shows the structural model.

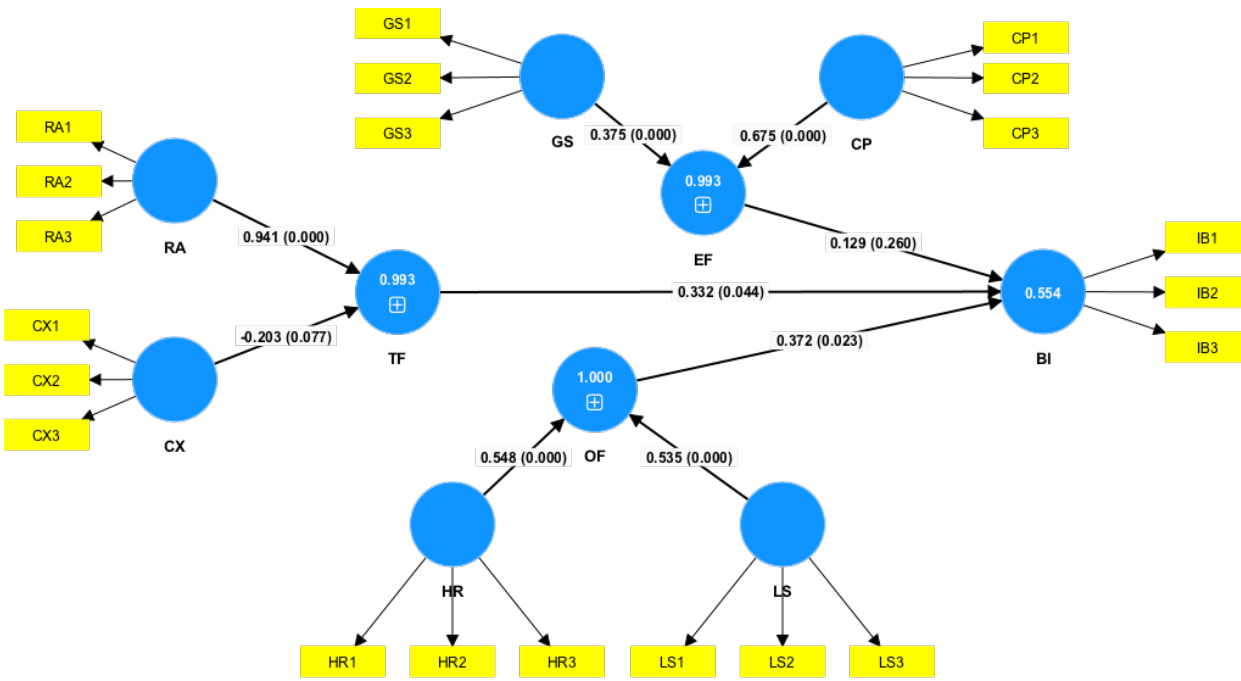

Figure 5.2: Structural model.

To assess the hypotheses, we first conducted significance tests for the path coefficients. According to (94), path coefficients should demonstrate a "t-value" exceeding 1.645 at a significance level of 0.05 and surpass 2 at a significance level of 0.01. As illustrated in Table 5.11, technological factors (TF) ($\beta = 0.332$, $p < 0.05$) significantly influence behavioral intention (BI) toward the adoption of blockchain technology in Saudi healthcare data management. Therefore, Hypothesis 1 is supported and has a positive influence on the adoption of blockchain technology in Saudi healthcare management. In terms of organizational factors (OF) ($\beta = 0.372$, $p < 0.05$), they significantly influence BI toward the adoption of blockchain technology. Therefore, Hypothesis 2 is supported and has a positive influence on the adoption of blockchain technology in Saudi healthcare management. However, environmental factors (EF) ($\beta = 0.129$, $p > 0.05$) do not demonstrate significant effects on BI. Hence, Hypothesis 3 is not supported and does not have a positive influence on the adoption of blockchain technology in Saudi healthcare management.

Hypothesis	**Path**	**Path Coefficient**	**T-value**	**p-value**	**Decision**
H1	TF-BI	0.332	2.019	0.04	Supported
H2	OF-BI	0.372	2.309	0.02	Supported
H3	EF-BI	0.129	1.133	0.26	Not Supported

Technological factors (TF), Organizational factors (OF), Environmental factors (EF), Behavioral intention (BI)

Table 5.11: Hypothesis testing results

The subsequent assessment of the structural model involved determining the coefficient of determination (R^2) for the dependent construct, namely BI. R^2 quantifies the proportion of variance in the dependent construct explained by the independent constructs (91). In our analysis, we observed an R^2 value of 0.554, indicating that technological, organizational, and environmental factors collectively accounted for 55.4% of the variance in the intention to adopt blockchain technology, as depicted in Figure 5.2.

Lastly, we evaluated the effect size (f^2), which indicates the impact of removing a specific independent construct on the R^2 value of the dependent construct (91). According to (95), f^2 values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. As depicted in Table 5.12, our findings for f^2 ranged from 0.0129 to 0.372. Organizational factors (OF) exhibited a large effect size, while technological factors (TF) and environmental factors (EF) showed medium and small effects, respectively.

Construct	**Effect Size (f^2)**
Technological factors (TF)	0.332
Organizational factors (OT)	0.372
Environmental factors (EF)	0.129

Table 5.12: Effect size (f^2) of constructs' results

5.5.3 Potential Implementations Suitable for Migration to Blockchain Technology

Participants were asked to recommend healthcare data management applications suitable for migration to blockchain technology. An analysis of their responses, depicted in Figure 5.3, indicated a predominant preference for transferring EHRs (46.5%) to blockchains, followed by health insurance (31%) and pharmaceutical supply chains (18.60%). However, there were fewer recommendations for the integration of clinical trials (2.30%) and laboratory information management systems (LIMS) (.8%) with blockchains. Notably, the participants did not specify any additional services under the "other" category.

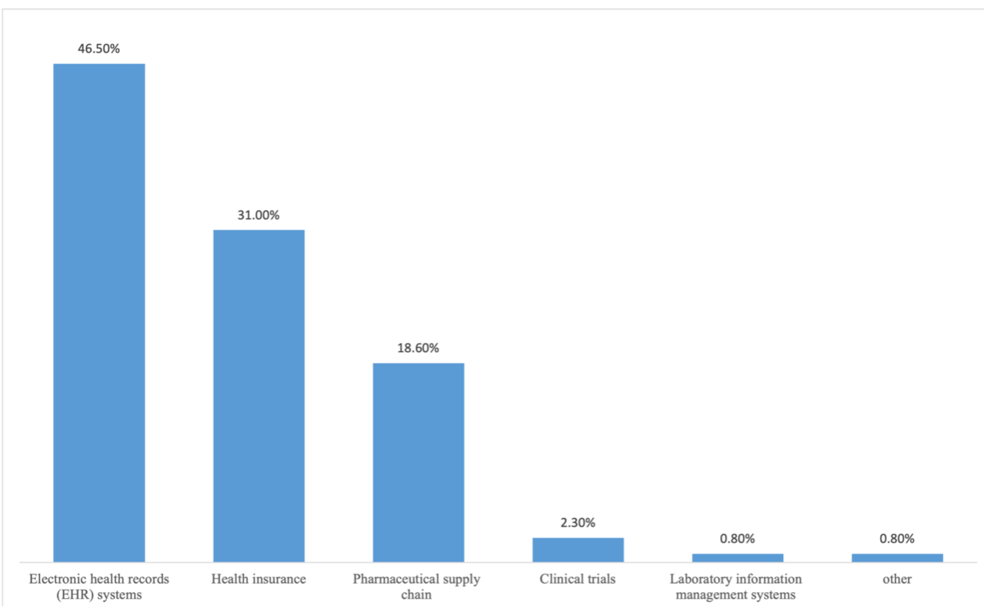

Figure 5.3: Implementations suitable for migration to blockchains.

5.5.4 Potential Adoption of Blockchain Technology in Saudi Healthcare Data Management

The participants were asked about their stance on the potential adoption of blockchain technology in Saudi healthcare data management. According to the findings illustrated in Figure 5.4, the majority of participants (65.10%) expressed support for integrating blockchain technology within healthcare data management, while (22.5%) maintained a neutral stance. In contrast, a small percentage (12.40%) were against the concept of adoption.

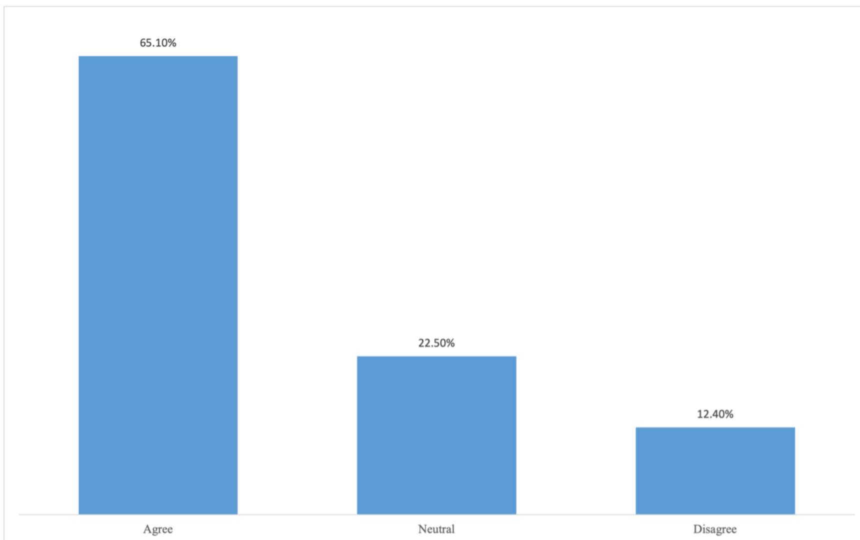

Figure 5.4: Potential adoption of blockchain technology in Saudi healthcare data management.

5.6 Discussion of Results

5.6.1 Technological Factors

The technological dimension, which encompasses equipment, functionalities, methods, and costs, plays a crucial role in shaping the adoption process (63). This study examined how various technological factors, such as relative advantage and complexity, may impact the adoption of blockchain technology in Saudi healthcare data management. We hypothesized that technological factors positively influence the adoption of blockchain technology in Saudi healthcare data management.

Our quantitative analysis indicates that these technological factors collectively have a substantial influence on individuals' behavioral tendency to adopt blockchain technology in Saudi healthcare data management ($\beta = 0.332$, $p < 0.05$). This finding is consistent with prior research demonstrating that institutions derive substantial benefits from the relative advantage of technology in adopting blockchain technology (6),(67),(68),(69). Similarly, our findings suggest that the complexity of technology does not significantly hinder blockchain adoption, which reflects previous research findings (6). This suggests that healthcare organizations prioritize the benefits of integrating blockchain despite its complexity, including enhanced data integrity and security through the encryption of MHRs (69), improved interoperability, which is one of the most important healthcare system requirements, immutability of unified healthcare records, and auditability (13).

To facilitate adoption, healthcare organizations should conduct training sessions to educate their employees about the benefits of blockchain technology, thereby increasing awareness and fostering acceptance and support for implementation. The training sessions should encompass the fundamental principles of blockchain technology and practical examples of its implementation in the healthcare industry, showcasing quantifiable advantages like enhanced data security, improved interoperability, and optimized workflows. While complexity may not be a significant barrier to adoption, according to the findings, hospitals should still address any perceived complexities associated with blockchain technology by providing resources and support to help staff navigate challenges during the adoption process. For instance, hospitals can integrate blockchain technology into non-critical systems, such as inventory management systems, to familiarize staff with its usage and ensure compatibility with existing systems.

5.6.2 Organizational Factors

The organizational context, comprising an organization's characteristics and resources, such as its management structure and size, significantly influences decisions regarding the adoption of blockchain technology (63). This study suggests that healthcare providers' readiness and leadership support are critical factors affecting the adoption of blockchains in healthcare data management in Saudi Arabia. We hypothesized that organizational factors have a positive impact on the adoption of blockchain technology in Saudi healthcare data management.

Our quantitative analysis demonstrates that organizational factors collectively exert a significant influence on individuals' behavioral preference to adopt blockchain technology in Saudi healthcare data management ($\beta = 0.372$, $p < 0.05$). This finding is consistent with the existing literature, which also suggests a positive correlation between blockchain adoption and healthcare providers' readiness and leadership support (13),(69),(72),(67),(71),(68). Consequently, hospitals with higher levels of readiness and leadership support are more likely to adopt blockchain technology in healthcare data management.

Therefore, healthcare organizations should invest in resources, including financial, technical, and skilled employees, to support the adoption of blockchain technology. Additionally, leaders, as decision-makers, should have enough knowledge about blockchain technology and its benefits to gain their support for adopting it. This support could be achieved by allocating necessary resources and organizing workshops to educate staff about blockchain benefits. Moreover, leadership should update policies and regulations to accommodate blockchain technology in healthcare data management. This may involve changing data privacy and security protocols to align with blockchain ledgers' decentralized and immutable nature, ensuring that patient data remains secure and tamper-proof. Leadership must involve front-line employees who directly engage with this technology in the decision-making process to ensure their perspectives and insights are considered, thereby increasing the probability of successful adoption and implementation.

5.6.3 Environmental Factors

The impact of external and inter-enterprise environments on businesses, known as the environmental context, is crucial to consider (63). In this study, we focus on the adoption of blockchain technology in healthcare data management in Saudi Arabia, which is expected to be influenced by two main factors: governmental support and competitive pressure. We hypothesized that environmental factors would positively affect the adoption of blockchain technology in Saudi healthcare data management.

However, our quantitative analysis revealed otherwise. The data showed that environmental factors collectively did not significantly influence the adoption of blockchain technology in Saudi healthcare data management ($\beta = 0.129$, $p > 0.05$), contrary to the existing literature (72),(67),(69),(77),(79),(71),(6). One potential reason for the insignificant impact may derive from the early stage of blockchain technology's development, coupled with the absence of comprehensive government regulations governing its application in the healthcare industry. Consequently, any alterations to existing regulations or legislation may impede or restrict the utilization of blockchain during this nascent phase. Another likely reason may be explained by the composition of our respondent pool, with more than half representing government and semi-government organizations. Given this, it is expected that the Saudi government, particularly the MOH, will provide substantial support to encourage blockchain adoption. For instance, initiatives such as the unified national database NAPHIS align with the government's Vision 2030 and demonstrate a commitment to digital transformation in healthcare that has unlimited governmental support to be implemented successfully (37).

To enhance blockchain adoption, healthcare organizations should engage with regulatory authorities to propose updated regulations that encompass essential concepts of blockchain technology, such as consensus mechanisms, smart contracts, and data ownership, because the current regulations often do not adequately address these aspects, hindering the seamless integration of blockchain in healthcare practices. Increasing awareness among healthcare stakeholders about the benefits of blockchain technology is also crucial to address any misconceptions and drive adoption forward. Additionally, collaboration with the private sector and research organizations can accelerate the development of blockchain-based solutions tailored to healthcare needs. Healthcare organizations should evaluate the implementation continuously by gathering feedback from stakeholders, monitoring performance metrics, and making adjustments to optimize the use of blockchain technology in healthcare.

5.6.4 Healthcare Data Management System Applications Proposed for Migration to Blockchain

Healthcare data management involves essential tasks for handling medical data, including acquisition, entry, processing, coding, outputting, retrieval, and storage across various healthcare systems (14). These systems encompass EHRs, clinical trials, health insurance, pharmaceutical supply chains, and so on.

This research requests participants to share their perspectives on which healthcare data management applications should transition to blockchain technology. The results strongly advocate for migrating EHRs to blockchains. Participants noted the characteristics of blockchains, such as immutability, transparency, distribution, and decentralization, as potential solutions to address existing challenges concerning privacy, security, accessibility, and interoperability. Following EHRs, the participants stressed the importance of considering blockchain adoption in health insurance systems, believing it could enhance the efficiency of the health insurance claim process. Additionally, the participants suggested transitioning pharmaceutical supply chains to blockchain technology, citing its potential to improve the tracking of medicine sources, thereby reducing the risk of counterfeit medications (47).

Moreover, the participants were asked to provide their viewpoints on adopting blockchain technology in Saudi healthcare data management. The findings revealed that a significant portion of the respondents supported incorporating blockchain technology into healthcare data management within the Saudi context, signaling a favorable stance toward its expected advantages. This underscores the significance of enhancing awareness among healthcare professionals and utilizing this favorable opinion to motivate adoption efforts.

Chapter 6

Conclusion and Recommendations

6.1 Conclusion

Blockchain technology is a notable advancement in digital innovation, yet its adoption, especially in sectors such as healthcare, remains at an early stage due to limited understanding and acceptance among users. In Saudi healthcare data management, there is no evidence of the utilization of blockchain technology. Thus, this study aimed to investigate the factors influencing its adoption in Saudi healthcare data management, focusing on the perspectives of healthcare organizations' employees. Using the Technological, Organizational, and Environmental (TOE) framework, the study aimed to provide insights crucial for decision makers to formulate effective strategies and mitigate project failure risks.

From a systematic review of previous studies, three key factors emerged as critical determinants of blockchain adoption: technological, organizational, and environmental. Technological factors, encompassing relative advantage and complexity, significantly shape organizations' perceptions of blockchain technology. Organizational factors, including healthcare providers' readiness and leadership support, play a pivotal role in fostering a positive attitude toward blockchain adoption. Environmental factors, such as government support and competitive pressure, also exert an influence on its adoption. Based on these findings, a theoretical research framework was developed and practically tested using an online survey administered to healthcare organization employees in Saudi Arabia. The collected data were analyzed using the PLS-SEM technique with SmartPLS 4.0 software to identify the significant factors influencing healthcare employees' behavioral tendencies.

Our study support two out of the three hypotheses proposed. The results reveal a notable influence of technological factors on the intention to adopt blockchain technology in healthcare management. Specifically, the relative advantage and complexity of blockchains emerged as critical drivers influencing adoption decisions within Saudi healthcare organizations. Hence, it is recommended that these organizations learn from past experiences with blockchain technology and recognize its comparative advantages in privacy, security, and interoperability to support confidence in its adoption. Moreover, organizational factors, such as readiness and leadership support, emerged as crucial determinants of blockchain adoption. The study emphasizes the importance of top management's favorable attitude toward the technology, the provision of adequate technical and financial support, and involvement in updating regulations and policies. Environmental factors have less impact on adoption intention; however, fostering government support initiatives, collaborating with the private sector, clarifying policies, and increasing awareness among healthcare stakeholders were identified as essential strategies to drive adoption efforts forward. Regarding prioritizing healthcare data management applications for blockchain migration, EHRs, health insurance, and the pharmaceutical supply chain are identified as top preferences based on the participants' opinions. Decision makers should consider these findings when formulating implementation strategies. Overall, the majority of the respondents favored the adoption of blockchain technology in Saudi healthcare data management, indicating a positive attitude toward its potential benefits. This highlights the importance of increasing awareness among healthcare employees and leveraging it positively to drive adoption efforts forward.

Practically, the study findings offer valuable guidelines for decision makers, particularly within the MOH, to develop regulations and policies promoting blockchain adoption among

Saudi healthcare organizations. Theoretical implications include contributing to the growing body of literature on blockchain adoption intention in Saudi healthcare and laying the groundwork for future research initiatives. Thus, this study contributes to advancing the knowledge and understanding of blockchain technology adoption in healthcare, particularly within the unique context of Saudi Arabia.

6.2 Recommendations for Future Research

1. This study focused solely on examining the reception of the adoption of blockchain technology in Saudi healthcare data management, considering technological, organizational, and environmental aspects. However, there is the potential to broaden the scope of inquiry by incorporating regulatory and legal factors, as well as cultural and societal factors, into future investigations.

2. This study primarily centered on healthcare data management as a whole. Subsequent research efforts could build upon our findings regarding the prioritization of healthcare data management applications suitable for migration to blockchain technology. For instance, emphasis could be placed on integrating systems such as EHRs, healthcare insurance, and pharmaceutical supply chains onto blockchain platforms.

3. This study offered significant insights into the determinants affecting the adoption of blockchain technology in Saudi healthcare data management, as perceived by healthcare personnel. In forthcoming research, exploring the obstacles and prospects associated with integrating blockchain technology into the current healthcare system is imperative.

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Appendix A

Institutional Review Board (IRB)

Florida Institute of Technology
Institutional Review Board

Notice of Exempt Review Status
Certificate of Clearance for Human Participants Research

Principal Investigator:	Noura Alkhalifah
Date:	February 5, 2024
IRB Number:	24-009
Study Title:	Investigating Factors Influencing Block chain Adoption in Saudi Healthcare Data Management

Your research protocol was reviewed and approved by the IRB Chairperson. Per federal regulations, 45 CFR 46.101, your study has been determined to be minimal risk for human subjects and exempt from 45 CFR46 federal regulations. The Exempt determination is valid indefinitely. Substantive changes to the approved exempt research must be requested and approved prior to their initiation. Investigators may request proposed changes by submitting a Revision Request form found on the IRB website.

Acceptance of this study is based on your agreement to abide by the policies and procedures of Florida Institute of Technology's Human Research Protection Program (http://web2.fit.edu/crm/irb/) and does not replace any other approvals that may be required.

All data, which may include signed consent form documents, must be retained in a secure location for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Access to data is limited to authorized individuals listed as key study personnel.

The category for which exempt status has been determined for this protocol is as follows:

2. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

    a. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; or

    b. Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

    c. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and IRB can determine if there are adequate provisions in place to protect the privacy of the subjects and confidentiality of the data.

Appendix B

Survey

Factors Influencing the Adoption of Blockchain in Saudi Healthcare Data Management

Thank you for participating in my survey! I invite you to join a research study about "Factors influencing the adoption of blockchain in Saudi healthcare data management." Before starting, I want to ensure you know why we are doing this and what it involves. Take a moment to read the information carefully.

* Required

Purpose of the Survey

While blockchain technology offers benefits such as enhanced security, its complexity and associated costs need careful consideration before adoption. Thus, this study aims to explore the factors affecting the adoption of blockchain in Saudi healthcare data management.
This survey requires 10-15 minutes to be completed. Your responses will be kept secret. The survey questions focus on the factors influencing the adoption of blockchain in Saudi healthcare data management in terms of technological, organizational, and environmental factors.
If you have any additional questions, please do not hesitate to contact me.
Email: nalkhalifah2021@fit.edu
Your participation is valuable, and your privacy is our priority.

Participant Background

1. **Educational level** *

- ◯ Diploma Certificate
- ◯ Undergraduate Degree
- ◯ Postgraduate Degree or Higher
- ◯ Other

2. **Professional status** *

- ◯ Doctor/Physician
- ◯ Nurse
- ◯ Administrative Staff
- ◯ Allied Health Professional (e.g., physiotherapist, pharmacist)
- ◯ Medical Student/Intern
- ◯ IT Specialist
- ◯ Health Information Management Specialist
- ◯ Other

3. **What type of organisation you are employed in?** *

- ◯ Government
- ◯ Semi-government
- ◯ Private

Experience and familiarity with blockchain technology

A brief description of blockchain technology :

Blockchain is a collection of secure and unchangeable data records handled through a group of computers not owned by a central authority. Cryptographic concepts ensure the security of these data blocks and chain them together.

In the healthcare context, blockchain can enhance interoperability between systems, efficiently handle large data volumes, and provide transparent, unalterable unified health records that are accessible globally. It also can potentially enhance medical records management and streamline insurance claim processes. Additionally, blockchain empowers patients to own and control their data without compromising safety or limiting the sharing of healthcare services.

4. **Please evaluate your computer skills using the following scale:** *

○ Basic

○ Moderate

○ Advanced

○ Expert

5. **Please evaluate your knowledge of blockchain technology:** *

○ None

○ Basic

○ Moderate

○ Advanced

Survey Questions

Please express your level of <u>agreement or disagreement</u> with each statement:

6. **<u>Technological Factors</u>**

1- Relative advantage

In your opinion, health organizations choose to adopt blockchain when they believe that:
*

	Strongly Disagree	Disagree
Blockchain provides Immutable unified health records.	◯	◯
Blockchain enables medical records that are distributed between health industry to be accessed from any location.	◯	◯
Blockchain increase the accuracy of medical information.	◯	◯

7. **2-Complexity**

In your opinion, health organizations <u>may not adopt</u> blockchain when they believe that:
*

	Strongly Disagree	Disagree
Integrating blockchain into existing medical systems is a challenging task.	◯	◯
Learning to use blockchain in medical systems is complex.	◯	◯
Blockchain adoption demands complicated technical skills from hospital staff.	◯	◯

8. **Organizational Factors**

1- Hospital readiness

In your opinion, health organizations choose to adopt blockchain when they believe that: *

	Strongly Disagree	Disagree
The hospital's IT infrastructure is ready to adopt blockchain.	◯	◯
Adequate IT human resources are available in the hospital for adopting blockchain.	◯	◯
Sufficient financial resources are available in the hospital to adopt blockchain.	◯	◯

9. **2- Leadership support**

In your opinion, health organizations choose to adopt blockchain when they believe that: *

	Strongly Disagree	Disagree
The leadership strongly encourages the adoption of blockchain.	◯	◯
The leadership provides essential resources (such as finances, workers, and materials) to support the adoption of blockchain.	◯	◯
The leadership is ready to take the risks associated with adopting blockchain technology.	◯	◯

10. **3- Environmental factors**

1- Government support

In your opinion, health organizations choose to adopt blockchain when they believe that: *

	Strongly Disagree	Disagree
The government financially funds the adoption of blockchain.	◯	◯
The government establishes regulations and policies to encourage the adoption of blockchain.	◯	◯
The government encourages the adoption of blockchain by offering support for training initiatives within hospitals.	◯	◯

11. **2- Competitive pressure (CP)**

In your opinion, health organizations choose to adopt blockchain when they believe that: *

	Strongly agree	Do not know
They experience pressure when their competitors have already adopted blockchain.	○	○
They observe their competitors gaining advantages from adopting blockchain.	○	○
They fear losing a competitive advantage if they do not adopt blockchain.	○	○

12. **Which hospital systems should be considered to adopt blockchain technology within its system?** *

- ○ Electronic Health Records (EHR) Systems
- ○ Pharmaceutical supply chain
- ○ Clinical trials
- ○ Health insurance
- ○ Laboratory Information Management Systems
- ○ Other

13.

To what extent do you support the implementation of blockchain technology in Saudi healthcare data management? *

- ◯ Agree
- ◯ Neutral
- ◯ Disagree
