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Assessment of the Blockchain Technology Adoption for the Management of the Electronic Health Record Systems

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Assessment of the Blockchain Technology Adoption for the Management of the Electronic Health Record Systems

by

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ABSTRACT

Blockchain is an emerging technology that holds great promises in healthcare despite slow adoption and previous unsuccessful implementation projects. Blockchain adoption in healthcare has been slow, partly because healthcare is a heavily regulated and complex industry. Blockchain applications span various areas of healthcare such as patient data management, health information exchange, health supply chain management, financial and insurance claims, clinical trial, biomedical devices tracking, and pharmaceutical counterfeit. The main challenges with blockchain technology in healthcare are: scarcity of real applications, the high level of failing projects, and the need for various parties to function together. There is, however, a lack of research on how to assess the adoption and help healthcare organizations use blockchain for the management of the electronic healthcare records (EHR) systems in a comprehensive way incorporating multiple perspectives. The objective of this research is to develop a scoring model to evaluate healthcare organization's readiness to adopt blockchain for the management of the EHR systems.

In this research, a literature review and expert feedback were used to identify the most important factors influencing blockchain adoption. The focus is on the application of the blockchain technology adoption for the management of the EHR systems. The Hierarchical Decision Modeling (HDM) methodology was used to elicit multiple expert's judgment to identify the relative importance of those factors influencing blockchain adoption. In addition, experts' feedback was used to identify the possible statuses an organization might have regarding each factor and the dynamic aspects of these factors was analyzed. Finally, two case studies of the blockchain adoption, Oregon Health and Science University (OHSU) hospital and a Medical City in Saudi Arabia, were conducted to demonstrate the practicality and value the research model brings to the research objective.

The outcomes of the research present an identification of blockchain adoption impacting factors and their resultant rankings. The research identifies 17 factors as the most important factors influencing blockchain adoption and a healthcare organization's readiness for adoption. The factors are grouped into five perspective: financial, social, technical, organizational, and regulations & legal. The case studies are used to demonstrate how the model could be used to identify areas of deficiencies and propose corrective actions in the healthcare organization's capabilities. The goal is to prevent any possible issues, before the project starts, in order to increase chances of a successful blockchain adoption.

DEDICATION

To my Parents, my mother Fatimah and the memories of my father Mohammed may Allah have mercy upon him. Without them, I would not be where I'm in my life. Without my mother's guidance, support, encouragement, and prayers, I would not have achieved this goal.

To my wife, Maram, whose love and support is endless. She stood by my side for bad and for good and supported me.

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CHAPTER 1: INTRODUCTION

Information Technology (IT) has become a crucial part of the healthcare system and it is getting more attention worldwide. Health IT, as it is called, includes well-known systems that have transformed the healthcare industry, such as Electronic Health Records (EHR), Electronic Medical Records (EMR), and Electronic Personal Health Record (ePHR). These systems aim to enable high-quality healthcare. In the U.S., the Office of the National Coordinator for Health Information Technology (ONC) shows that the non-federal acute care hospitals with certified EHR rate increased from 9% in 2008 to 84% as of 2015 [1].

The Health IT models have been evolving in recent years. The American Recovery and Reinvestment Act of 2009 (ARRA) [2] was passed to incentivize and aid the Healthcare IT sector with over $20 billion to support the development of Health IT infrastructure and to encourage involved parties to adopt and use Health IT through the meaningful use program. The meaningful use aims to widen the adoption of certified EHR for the goals of [3]:

- Improve quality, safety, efficiency, and reduce health disparities
- Provide patient-centered healthcare by engaging patients in their health care
- Improve population and public health
- Maintain privacy and security of healthcare information

This research is focused on blockchain adoption in healthcare. Blockchain holds great promises in healthcare despite the slow adoption and unsuccessful past implementations. Blockchain adoption in healthcare is slow, partly because healthcare is a heavily regulated and complex industry as it has a direct impact on public health so there are many regulations and requirements to comply with. Healthcare, however, is believed to have more potential blockchain applications than probably any other industry beside the financial industry. Blockchain applications span various areas of healthcare such as patient data management, health information exchange, health supply chain management, financial and insurance claims, clinical trials, biomedical device tracking, and pharmaceutical counterfeits. The main challenges with Blockchain technology in healthcare are the scarcity of real applications, the higher level of failing projects, and the need for various parties to function together. Unfortunately, there is a lack of research on how to assess and subsequently help Healthcare organizations adopt blockchain technology for the management of the EHR systems. Therefore, the objective of my research is to develop a scoring model to evaluate healthcare organization's readiness to adopt Blockchain technology for the management of their EHR systems.

1.1 Research Motivations

The issues with the current healthcare systems have mandated the exploration and adoption of various technologies to address said issues. These issues include: security and privacy of the patient's protected health information, interoperability, health information exchange, healthcare waste (administrative and transaction costs), and efficiency. The following are cited examples of the current issues in the U.S. healthcare system:

- It is estimated that U.S. healthcare waste totaling $700 Billion [4], accounting for 20% of the U.S healthcare expenditures [5]. Also, the administrative costs account for 34.2% ($812 billion) of the U.S healthcare expenditures [6].
- In 2018, the Department of Health and Human Services' Office for Civil Rights (OCR) received notifications of 351 data breaches of 500 or more healthcare records, which in total resulted in the exposure of 13,020,821 healthcare records. In 2017, there were 359 data breaches of 500 or more records reported to OCR, which resulted in the exposure of 5,138,179 healthcare records [7].
- The number of individuals affected by protected health information breaches between 2014 and 2015 increased from about 1.8 million to approximately 111.9 million [8]. Reports show that 6 out of the 10 top breaches are "Hacking/IT incident" type of breach for the year of 2018 [9].
- Patients records are scattered across different healthcare facilities, and the current EHR systems are not meant to create a lifetime record of the patient history [10]
- Studies show that due to interoperability issues between the healthcare providers, about 30% of tests are reordered because the results cannot be found or are of no benefit [11].
- The current state of EHR shows that around 40% of physicians consider EHR design and interoperability as primary sources of dissatisfaction (A study on a sample size of 8,774 physicians) [12].
- It is estimated that less than 10% of healthcare organizations regularly share medical information with providers outside of their organization [13].

- Lyu et al. [14] surveyed 2,106 physicians to examine their perception of the overtreatment as a cause of preventable harm and waste in health care problems. The study indicates that 20.6% of overall medical care was unnecessary. The sources of waste include prescription medications (22%), tests (24.9%), and procedures (11.1%) [14]. Also, reasons of overtreatment include fear of malpractice (84.7%), patient pressure/request (59.0%), and difficulty accessing medical records (38.2%) [14].

Blockchain technology is believed to provide a solution to these issues. Section 2.6 discusses in detail these issues and how blockchain technology can solve them.

One example of a healthcare system issue where blockchain can be of a great benefit is in the inefficient and redundant tasks across the healthcare systems. More than $2.1B is spent annually on inefficient and redundant tasks involving hospitals, doctors, and health insurers that maintain provider data [15] [16]. CMS found that 52 percent of provider directory locations listed had at least one inaccuracy. Currently, the Synaptic Health Alliance; Aetna, Ascension, Humana, Multiplan, Optum, Quest Diagnostics, and UnitedHealthcare; have formed a group to implement a permissioned blockchain solution to improve accuracy of provider data. The solution will allow members to view, input, validate, update and audit non-proprietary provider data within the network [16]. The proposed solution aims to reduce operational costs while improving data quality.

1.2 Problem Statement

Blockchain technology is a new concept that emerged in recent years as a platform to facilitate the management and exchanges of patient records and serve as a platform for various applications across different industries. The literature has proven the value Blockchain can bring to different businesses and industries, including how blockchain help overcome various issues on the current healthcare systems (refer to section 2.5.2.2 for more details on the blockchain benefits). There is a lack of studies that assess blockchain adoption for management of EHR systems. The research investigated, in the literature review, regarding the adoption of the blockchain for EHR systems is limited to identifying blockchain benefits and challenges; and how blockchain provides better management of the EHR system.

Katuwal et al. investigated blockchain literature to examine the blockchain technology applications and implementations in the management of patient records and concluded that" most of the blockchain projects are limited as white-papers, proof of concepts, and products with a limited user base. However, we observed that the quantity, quality, and maturity of the projects are increasing" [17]. Yet, blockchain implementations have been struggling to succeed. Studies indicate that a higher percentage of the blockchain technology projects fail or should never have started in the first place. Failure is due to various reasons such as the hesitance of the healthcare organization toward blockchain adoption, the lack of realizing the potential value blockchain can add, and the organization's readiness for adoption.

The current models of the blockchain are immature, can be challenging to scale, are poorly understood, and unproven in mission-critical environments [18]. However, blockchain projects are maturing rapidly where implementations are moving quickly beyond the pilot and proof of concept phase [19]. Business challenges of blockchain are often more significant than those posed by technology itself [20]. Kshetri stated that the main barriers to introducing blockchain might be educational rather than technical [21]. On the other hand, recent reports show that a high number of blockchain projects are either shutting down or scaling back in terms of goal and timeline [22]. These failed projects are either never complete or do not generate the expected value. It is estimated that 90% of these projects will not survive to be operational [22]. Additionally, Forrester tracked 43 blockchain projects that proposed blockchain as revolutionary in their respective industries and concluded that none of these examined projects had achieved their full implementation objectives [23]. According to the VP of the Forrester, "In 2018, we expect to see a number of projects stopped that should never have been started in the first place." [24]. The section (2.5.2.3) points out the main challenges of the blockchain technology adoption among healthcare organizations.

The adoption and implementation of blockchain technology involves serious changes in the healthcare organization's culture, infrastructure, and how organizations conduct business, meaning it is very costly to fail. The success of the blockchain projects depends on internal and external factors; such as, the skills to build blockchain solutions and the fixability of the regulations surrounding blockchain. Healthcare organizations should consider various internal and external factors in order to ensure successful blockchain adoption. Having a mechanism that facilitates the assessment of healthcare organizations readiness for transformative adoption is required in order to: identify the most important factors impacting successful blockchain adoption, assess their readiness to adopt blockchain, and to point where corrective actions are needed.

CHAPTER 2: LITERATURE REVIEW

2. 1 Health Information Technology

Health information technology (HIT) allows healthcare organizations to benefit from information and communication technology (ICT) advancements to better manage patient's care using computerized systems. HIT allows for secure use and sharing of relevant health information, which improves health care decision making and ensures high-quality care. Among the computerized systems that have transformed the healthcare industry are the Electronic Medical Records (EMR) and Electronic Health Records (EHR). Electronic Medical Records (EMR) contain all of the patients health information; health problems lists, labs results, physicians notes, and radiology results; aggregated from a single healthcare provider [25]. A single patient may have multiple EMRs from different hospitals or physician offices. The U.S. Centers for Medicare & Medicaid Services defines the Electronic Health Record (EHR) as "an electronic version of a patient's medical history, that is maintained by the provider over time, and may include all of the key administrative clinical data relevant to that persons care under a particular provider, including demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports" [26]. What differentiates the EHR from EMR is that EHR contains patient's health records from multiple healthcare providers. The benefits of EHR include: improved patient health care, increased patient engagement, improved efficiency and cost reduction, improved quality of care and outcomes, and enhanced care coordination [27].

2.2 Importance of Health IT

The growth of the healthcare sector expenditure mandates finding new ways to provide high-quality care while reducing costs. The U.S. spending in the healthcare sector was $3.3 trillion in 2016 and is growing by 4.3% which represents about 17.9% of the nation's GDP [28]. In 2018, the U.S. health care spending increased by 4.6 percent, reaching $3.6 trillion [29]. The U.S. national health spending is expected to grow at an average rate of 5.5% annually for 2018-2026 to reach $6.0 trillion by 2027 [29]. The growth of the hospital expenditures was 4.5% ($1,142.6 billion) in 2018 compared to 4.7% growth in 2017 [29].

The healthcare system is very complex and costly. Administrative costs accounted for 34.2% ($812 billion) of the U.S healthcare expenditures [6]. In the U.S., The American Recovery and Reinvestment Act of 2009 (ARRA) focuses on health information technology-related funds [2]. The HIT sector was aided by over $20 billion to support the development of HIT infrastructure and to encourage involved parties to adopt and use HIT solutions [2]. The ARRA considers the EHR as a significant element of national policy which aims at achieving the goals of improving the quality of care, safety, efficiency, and reducing costs.

EHR helps to avoid unnecessary or duplicated tests or labs. One study found that such a computerized system helps in blocking about 11,790 unnecessary duplicate test orders in just two years that would have cost around $183,586 [30].EHR helps reduce staff workload, which means low cost of overhead [31]. Computerized systems such as

EHR can provide a better quality of care, service and treatments which consequently: reduce costs, reduce unnecessary consultations, reduce waiting lists, and allow patients to benefit from participating in online prescription ordering services. EHR would improve the efficiency of the pharmacist's work and reduce the time spent fulfilling the prescription in the traditional way [32]. EHR can be used to deliver administrative services to patients that would be costly to do in the conventional way. Administrative cost-saving comes from: lab/test result mailing costs, online billing inquiries compared to making phone calls, online appointment scheduling, and appointment reminders [33].

Studies showed that productivity increases when physicians use electronic media to communicate with their patients. One study found out the physicians' productivity increased by 10% and they were able to see more patients per day [34]. Kaelber and Pan studied the value of patient engagement through PHR systems and concluded a significant net benefit to the US healthcare system through steady state annual net value ranging from $13 billion to -$29 billion in potential cost savings to the healthcare system at the course of ten years [35].

2.3 Types and EHR Implementations

There are three classifications of EHRs that are identified by the ONC and adopted by the Office-based Physicians and hospitals [36]: Certified EHR, Basic EHR, and Any EHR. The EHR is defined in section (2.1 Health Information Technology). ONC aims to incentivize healthcare organizations to adopt certified solutions. The certified EHR is the type of system that is approved by the US Department of Health and

Human Services and meets its criteria [36]. Certified EHR should comply with the Promoting Interoperability (PI) Programs, which is an extension of the meaningful use initiative [37]. Certification also helps health care providers and patients be confident that the electronic HIT products and systems they use are “secure, can maintain data confidentially, and can work with other systems to share information” [37]. These systems should provide patients with engagement capabilities, such as giving the patients the ability to exchange secure messages with their physicians and to view, download, and transmit their online records [38].

The HIT models have been evolving in recent years. There have been different models designed to store, manage, and exchange patient’s data. Two popular EHR implementations that healthcare organizations have adopted include Provider’s EHR, and National or Universal EHR.A third implementation could be blockchain for EHR systems.

- Provider’s EHR: Health Records are stored internally and exchanged through RHIEO or directly between health care organizations [39] → USA
- National EHR: nationwide EHR that is connected with providers’ EHR systems → Estonia is a successful example.
- EHR with a blockchain layer: distributed ledger where every participant/provider has the same copy of the records → proof of concept stage and prototypes.

The common practice in the United States is that the healthcare provider manages their patient EHR and exchanges necessary information through regional health information exchange (HIE) organizations. Te concept of national or universal EHR has been utilized in many countries across Europe, in Australia, Singapore, and in Estonia. In some European countries such as Estonia, healthcare providers manage their patient records and obliged to send certain parts of the records to a central national EHR. Patients and healthcare providers can then access patient data from other healthcare providers through a single national portal that facilitates access and exchange for medical purposes.

2.4 Current EHR Adoption Status

The HIT adoption level by healthcare providers is increasing at an accelerating rate. For example, the release of the incentives program by the U.S. Centers for Medicare and Medicaid Services has fostered the recent EHR adoption rate increase in the U.S. The percentage of office-based physicians with Electronic Health Record Systems has grown dramatically between 2004 and 2017 [36]. As of 2017, about 79.7% of the office-based physicians had adopted a certified EHR solution.

The U.S. National Center for Health Statistics conducted surveys in 2013 and 2014 to investigate the office-based physicians' electronic sharing of patient health information that shows the increase in patient engagement by utilizing their EHR capabilities [40]. According to surveys, 57% of physicians electronically shared health information with their patients in 2014 compared to 46% in the year of 2013. 52% of physicians exchanged secure messages with their patients in 2014 with an increase of about 30% than the previous year [40].

Hospitals are seeking to acquire certified HIT solutions as well. More than 90% of all hospitals had certified EHR systems as of 2015 [41]. About 99% of the large hospitals with 400 or more beds have the highest rate of possession of certified EHR followed by the Medium hospitals, 100 to 399 beds, with 97%. 95% of Critical Access hospitals had certified EHR. Small rural and urban, less than 100 beds, hospitals had the lowest rates at 93% [41].

Hospitals adopt EHR and utilize patient engagement capabilities and functionalities to improve the quality of care provided. Reports published by the ONC show that there is a significant increase in the percentage of hospitals that enable patients to view, download, and transmit their health information online. About 69% of the hospitals enabling in 2015; and 63% of the hospitals in 2015 using secure messaging to communicate with the patients () [42].

2.5 Blockchain Technology and Healthcare

2.5.1 Blockchain Technology Concept

2.5.1.1 History and Definition

Blockchain is considered a significant innovation that is expected to have significant impacts on various industries, such as financial and healthcare. Blockchain is a peer-to-peer network that was introduced by Satoshi in 2008 and came to market in 2009 with the emergence of the Bitcoin as the first application of the blockchain [43]. Blockchain holds great promise in the way we do business and may revolutionize many industries [44]. Blockchain is believed to be one of the most important technology trends that could influence business and society [45] as well as disrupt and construct the future of the internet [46].

Blockchain is looked at as more of a foundational technology rather than a disruptive one [43]. Blockchain is a foundational technology rather than a disruptive technology as it creates foundations for our economic and social systems [43]. As foundational technology, blockchain adoption involves two dimensions that affect its evolvement: novelty and complexity [43]. The novelty represents the degree to which a technology is new to the world. The novelty level determines the effort level in which it is required to educate users of the problems it solves. The complexity of the new technology represented by the level of ecosystem coordination involved to produce value. As a result of the complex nature blockchain can be indicated as a workflow platform or business process management.

There is no agreed-upon single definition for blockchain technology. Most authors define blockchain by its characteristics. One definition of the blockchain technology is that it "is an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and prominent way" [43]. Another definition is that blockchain is a "digitized decentralized ledger to allow record keeping of all peer-peer transactions without the need for a centralized authority." [44]. Moreover, Zhuang et al., 2018 defined blockchain as "a distributed ledger technology which keeps all transactions synchronized among users" [47]. All the transactions can be audited publicly by all the users inside the blockchain. Once a transaction occurs, the information can never be erased or changed." [47]. It is a distributed database of digital events [48]. Blockchain is excellent for recording activities because blockchain is a transparent and shared database

[43]. Data within a blockchain is protected from deletion, tampering, and revision [43]. Blockchain brings huge efficiencies and cost-effective solutions in many areas of the market [49]. The main characteristics include decentralized and transparent consensus, distributed ledger, trustless, security and immutability, and automation [49].

There has been a growing market for blockchain technology worldwide since 2016 [50]. In 2017, the global blockchain technology market was predicted to reach $339.5M in size and is forecasted to grow to $2.3B by 2021 [50]. Blockchain is expected to generate around $3.1T in business value by 2030 [51]. International Data Corporation (IDC) predicts that global spending on blockchain to reach $2.9 Billion in 2019 [19] and then $11.7 Billion in 2022 [52] compared to around $1.5 Billion in 2018. The compound annual growth rate is predicted to be 73.2% for the 2017-2022 forecast period [19].

2.5.1.2 Blockchain Characteristics

This section explains the key characteristics that represent the blockchain technology:

- Decentralization [43] [46] [48] [53]: this feature implies that a transaction can be conducted in a peer-to-peer nature without the need for a central authority to validate and process the transactions. Each participant has full access to the entire database and its complete history. Every participant has the right to verify transactions within the network without the need for a central authority. Transactions can be decentralized by integrating key technologies such as cryptographic hash, digital signature, and distributed consensus mechanism. This feature allows for significant cost reduction in the cost of the servers (developmental and operation costs) and mitigates the performance bottlenecks at the central server. Distributed consensus protocol ensures data integrity [54]. Decentralization ensures that no centralized authority exists that can be vulnerable and at the risk of security attacks [54].

- Persistency: Blockchain is tamper-resistant by design. The transactions are confirmed and recorded in blocks that are spread across the network. It is nearly impossible to tamper with it. Each transaction is validated and approved before being spread throughout the blockchain network [46].
- Anonymity: every transaction is visible to all the participants. Each participant on the blockchain has a unique identifier (a private and public keys). In the communication that occurs between the blockchain addresses, each participant can stay anonymous or identify themselves by providing proof of their identity to others. The traditional central authority can keep a record of the users and their private information. Blockchain allows for an improved level of privacy [46] [43].
- Immutability and Transparency: Blockchain is immutable, meaning that once a block is added to the chain, it cannot be removed or changed in any way [43].
- Auditability: Blockchain technology enables the traceability of transactions. Each transaction is validated and recorded with a timestamp. Each transaction can be traced to its previous transaction. Blockchain improves the traceability and transparency on the stored data [46].
- Smart Contract [55] [54]: it is system commands that are automatically filed and executed when certain conditions are met. The smart contract brings significant

benefits in many areas such as regulation of intellectual property, control accesses, and privileges, or even fraud-proof voting.

- Security [46] [48]: Blockchain is secure by design. Each user has a private key and a public key. The private key is used to sign the transactions, which then will be spread throughout the whole network. The public keys then used to access the transactions, which are visible to everyone in the blockchain network. The security of the blockchain is due to the use of hashing. Each block is sealed with a hash and any change in a transaction would result in a change in the hash and break the block from the chain. The blockchain does not rely on a trusted third party to process transactions as it depends on the participant to verify the transaction and ensure its validity.
- Irreversibility [43]: it is immutable, once a transaction is entered in the system, it cannot be deleted, altered, or changed. Blockchain stores data permanently through the utilization of computational algorithms that ensures recording on the database is permanent, chronologically ordered, and available to all other network participants.
- Computational logic [43]: it describes the "smart contract" feature of the blockchain which enables setting up algorithms and rules that automatically trigger transactions between participants.

2.5.1.3 How does Blockchain work

Blockchain consist of a series of blocks chained together to form a blockchain as the name implies. The blocks are chained together with complex computational algorithms. Each block consists of many transactions and holds a reference, previous block's hash, to the parent block and generates a hash that goes to the next block [44].

Each block is linked to its previous block and has a timestamp [55] [54]. Transactions are added to the blockchain when the market participants agree on its validity and verify it [48]. The consensus of most of the participating nodes makes the verification of the transactions. The consensus is reached if all the transactions in the block and the block itself are found valid [48]. Figure 1. below shows the sequence of the blocks in the blockchain and the data it contains.

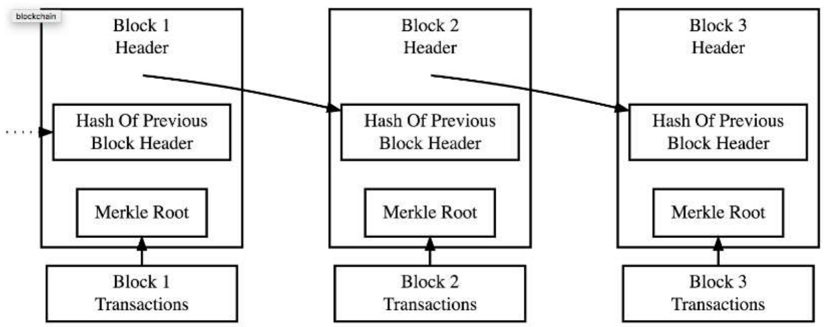

Figure 1. Blockchain design and data

2.5.1.4 Blockchain Trends and Predictions

Government agencies, technology organizations, consultancy firms, and business corporations consider blockchain as an essential technology trend that organizations should pay close attention to. Well-known technology organizations such as Deloitte, Gartner, HIS Markit, Forbes, Forrester, and the Government Accountability Office (GAO) have been tracking technologies that have the potential to transform businesses and society. Table 1 presents blockchain technology as a significant trend.

Table 1. Blockchain as a Significant Trend by Top Technology Trackers

Organization	Top Trends
Deloitte	Digital experience, cloud, analytics, Blockchain, cognitive, digital reality, Business of technology, core modernization, and cybersecurity [56].

Gartner	Autonomous things, Augmented analytics, AI-driven development, Digital twins, Empowered edge, Immersive technologies, and Blockchain [18].
IHS	cloud & virtualization IoT, AI, ubiquitous video, Blockchain, and 5G [57].
Forbes	Increased Automation, A Blockchain Comeback, Better Human/AI Collaboration, Expansion of Connected Devices, Inclusion of Augmented Reality in Most Apps, Upgraded Cybersecurity Using ML And AI, Solutions to The Tech Backlash, Technology Convergence, Augmented Analytics Using Natural Language, Growing Commitment to Data Security, Higher E-Commerce Sales of Everyday Items [58].
Forrester	Trends: IoT, DLT (Blockchain technology), Automated security intelligence, employee experience redefines apps, and software learn to learn (AI and Machine learning) [59].
The Government Accountability Office	Genome Editing, Artificial Intelligence and Automation, Quantum Information Science, Brain/Augmented Reality, and Cryptocurrencies and Blockchain [23].

The GAO, in its strategic plan for 2018-2023, considered blockchain technology as one of five emerging technologies and trends with the potential to affect and transform government and society [23]. Gartner Inc. has classified blockchain technology, under key platform-enabling technologies, as one of the top emerging technologies that organizations should track to gain a competitive advantage [60].

IHS Markit proposed a readiness score for six transformative technologies across key industries [57]. The readiness measurement is based on the average rating of the following measures for each technology: technology maturity, ease of use, affordability, security, organizational alignment, industry applicability, industry investment, industry attitude/support, business case, and executive support. The readiness score for each technology ranges from 1 to 7, with 7 being the readiest transformative technology. The technologies are: IoT, Blockchain, AI, Cloud and Processing, 5G, and ubiquitous video. Blockchain (3.64) and 5G (3.55) technologies were ranked the least among the six technologies in the readiness for widescale adoption. However, blockchain was ranked the highest based on security measurement [57].

2.5.1.5 Blockchain Types

Blockchain has two types of public ledgers: Permissionless-public ledgers and Permissioned-public ledgers. The access control is a key determinant in selecting the type of blockchain to be implemented.

Permissionless Blockchain

Permissionless-public ledgers operate “for any unknown or untrusted user with access to the ledger, and allow these users to participate in commercial transactions” [61]. Public Blockchain is permissionless since it does not have restricted access for selected nodes, that is everyone can join the network as a reader or as a writer. Transactions are stored in blocks on a public ledger and accessed by every member of the network [62]. Permissionless Blockchain has no central authority that manages, verifies, and monitors transactions within the blockchain network. Anyone joining the network can have a reader and writer privileges at any time [63].

Permissioned Blockchain

Permissioned-public ledgers operate “on behalf of a community of interest, but access controls are owned/managed by rules” [61]. The Permissioned Blockchain authorizes only a selected number of users to have read and write privileges. One or more entities determine the number of participants and grant rights to participating users [63]. Permissioned Blockchains are believed to provide better confidentiality, privacy, and scalability in addition to the functionalities of the original blockchains model [62].

Permissioned Blockchains can be used to store and transmit sensitive information such as healthcare records.

There are two types of permissioned blockchains: private blockchains and consortium blockchains. They both run on a private network. The access to the blockchain is restricted to a predefined set of entities.

Private Blockchain

In the Private blockchains, write permissions are centralized to one entity, whereas read permissions may be public or restricted to certain users [62]. Any authorized user will create a transaction or a block. The central authority validates and distributes the transaction to the different participants without the need for cryptographic hashing.

Consortium Blockchain

In Consortium Blockchain, the consensus process is controlled by a preselected set of trusted nodes. Consortium Blockchain is, to some extent, a decentralized system [62]. The validation of the transactions occurs by achieving the consensus from the preselected set of nodes. The different implementations and types of blockchain depend on a set of properties such as consensus, access control, consumption, and management [64]. The following Table 2 shows a comparison between the different types of blockchain implementations (Public vs Private).

Table 2. Public and Private Blockchain Properties

Property	Public	private	Consortium “federated.”
Participant (identity)	(Pseudo) Anonymous “untrusted.”	Identified users “trusted.”	Identified users “trusted.”

Access	Anyone	Single Organization	Multiple Organization
Verification Mechanism	decentralized	Centralized	Semi centralized (certain nodes can confirm)
Protocol Efficiency	Low efficiency	High efficiency	High efficiency
Power Consumption	High	Low	Low
Ownership	public	Centralized	Semi centralized
Management	Permissionless	Permissioned	Permissioned

Another way to investigate the blockchain types is based on the permission level as shown in the following table 3 [54].

Table 3. Public and Private Blockchain comparison

	Permissioned	Permissionless
Public	Only selected users can participate in the consensus mechanism or validate transactions. Open to anyone to read, and selected users can write.	The is no restrictions on reading data on the blockchain. Anyone can join the network. Participants can read, write, and validate.
Private	Limited access, writing, and validation. The owner determines the participants with the rights to validate transactions.	There are restrictions on access and who can participate in the consensus mechanism. Selected users can validate and read data.

Different industries and applications require unique and tailored blockchain implementation types. Based on the analysis of different characteristics of the different types of blockchain implementations, a private and permissioned implementation would be optimal [65]. The current traditional database may not satisfy the HIT requirements for interoperability and security. In the case of a private blockchain, access should be limited to the partners and healthcare organizations which share common goals. HIT data should be private to ensure the privacy of the patient's information and to ensure a high level of security. Permissioned Blockchain is the most effective type in sharing and managing EHR systems. Permissioned Blockchain makes it possible for different participants to share real-time data securely [21]. Scalability and privacy issues in the blockchain implementation make the private blockchain better fit with the healthcare requirements

[66]. A survey of more than 1,000 technology executives showed that around 52% of the respondent believes that Permissioned Blockchain is the most suitable implementation [66]. Furthermore, another survey of more than 1,300 executives, from countries across the globe, shows that senior executives from top companies believe that the Private and Permissioned Blockchain models are the most appealing implementations of the blockchain [67].

2.5.1.6 Blockchain Use Cases

There are a number of blockchain applications. Blockchain can be used in supply chain management, where traceability is essential. The life-long medical record of patients in the healthcare sector can be another application of blockchain in the ability to provide a historical view of the patient's records and overcome the problems of data silos. Blockchain has made a significant impact on the financial sector. Bitcoin and other cryptocurrencies have grasped the attention of many people, including regulators.

2.5.2 Blockchain in Healthcare

2.5.2.1 Overview

Technologists consider blockchain technology as the fourth industrial revolution and thus it will have a tremendous impact on the world. Blockchain is seen as a perfect technology for healthcare, addressing difficult and complex issues in the existing health system [68]. Blockchain, with respect to the healthcare system, is a distributed database that records and stores health records in the form of time-stamped “Blocks” linked to each other in such a way that no one can alter any record. Healthcare Informatics' editors considered it as one of the Top Technology Trends for HIT in 2017 despite the belief that it is still in the very early stage of its maturity [69]. The Blockchain technology market in healthcare is estimated to reach $5,5 billion by 2026 [70]. The global blockchain market in healthcare is expected to grow at a Compound Annual Growth Rate (CAGR) of 63.85% from 2018 to 2025 [13].

Healthcare providers have shown an interest in taking advantage of blockchain technology. Deloitte, in 2018, surveyed more than 1000 technology executives from companies with annual revenue of $500 million or more, located in seven countries, and operating in nine different industries; to examine where blockchain is headed [71]. About 11% of the surveyed executives are from the healthcare industry, and 55% of them believe that blockchain technology will disrupt healthcare industry. Around 74% of the technology executives in healthcare indicated that they have excellent or expert knowledge of blockchain technology. 63% of healthcare organization executives showed that they are planning to invest more than $1 million over the next calendar year in blockchain, and 39% believe that blockchain will be a critical (top-5 priority) for their organization [71].

Deloitte publishes a yearly report investigating the status of blockchain technology. In comparison to the same survey from 2018, respondents' positive attitude toward blockchain technology in the 2019 survey (of more than 1,000 senior executives) has improved regarding blockchain scalability, business case availability, collaboration with different participants, and moving forward with use cases [67]. Overall Executives believe that their organizational challenges and concerns have softened compared to 2018.

Blockchain utilization in the healthcare sector holds great promise to transform healthcare. The 2019 Deloitte report on blockchain shows an increased interest in the investments in blockchain technology projects [67]. More than 1,300 executives were surveyed from countries across the globe. Around 53% of respondents presented blockchain as a critical priority for their organization in 2019. The 2017 survey conducted by Cognizant on 588 respondents, familiar with blockchain, from healthcare organizations to understand how healthcare organizations view the potential of blockchain [72]. The survey revealed significant insights. 57% of the respondents predicted it will fundamentally transform the industry, and 51% of the respondents identified the clinical administration data interoperability (EMR, EHR) as a top potential use case their organizations planned to explore in the near future [72] [62].

Many potential blockchain use cases in healthcare have been identified. Health data management presents a great opportunity. Blockchain can bring high value. Medical records solutions are among the most popular applications for blockchain in health [73] [65]. Blockchain data management applications include global scientific data sharing for R&D, data management, data storage (cloud-based applications) and EHRs [74].

2.5.2.2 Blockchain Benefits

This section introduces the blockchain technology benefits in general and within the healthcare industry in particular. Blockchain generates various benefits due to its design nature. The characteristics of the technology drive specific benefits. Blockchain provides a higher level of transparency, improved privacy, ensured data integrity, one version of the truth, better data sharing, reduced cost, and increased efficiency.

Blockchain is a transparent system due to the immutability of the stored data [63] [54]. Blockchain is an immutable system. Once a transaction is recorded, it cannot be deleted or altered. Immutability allows for greater transparency as every participant in the network has the right to access the shared data [44]. Blockchain ensures data integrity [63]. Information in the blockchain cannot be altered, changed, or deleted, thus it is protected against misuse. The verification of transactions ensures that the transaction is valid and there is only one version of the truth to be distributed throughout the network.

The availability of a replicated version of the data in the centralized system is achieved by the replication of the data in physical servers and backups. In blockchain, only one version of the truth is exchanged and duplicated throughout the network [63]. If an individual system has been compromised, the user can re-download the data from the blockchain network. As a result of its nature as a decentralized database, it has been suggested that blockchain can significantly save cost and improve efficiency [75] [46]. Blockchain can protect data against some privacy issues, such as: data ownership, data transparency, auditability, and fine-grained access control [46].

Blockchain improves operational efficiency [49]. Efficiency is achieved by the ability of blockchain to provide an immutable and distributed record-keeping that is validated by community consensus. Organizations hold individual digital books of records stored in a central database that frequently require manual reconciliation, and thus promote data silos. Blockchain overcomes this issue of data silos and promotes efficient data sharing.

Security is in the heart of the blockchain [46] [48] [49].

- Blockchain does not rely on a trusted intermediary to process transactions which can put the system at risk of security attacks.
- No vulnerable single failure point exists in the blockchain system.
- Blockchain increases predictive capability due to the availability of historical information at the fingertips of the network participants [54].

Blockchain promotes technical efficiency. Technical efficiency involves: getting rid of backup storage services, having recovery mechanisms in place, and ensuring up-to-date fields. There is no single point of failure leading to an inherent backup mechanism [76].

Blockchain technology can serve as a platform to enable better utilization of advanced technologies such as: big data analytics, smart contracts, and artificial intelligence [46]. Blockchain can provide benefits at different s of organizations including: strategic, organizational, economic, informational, and technological [54]. Blockchain can overcome many political, economic, social-technical issues. It provides transparency because all transactions are published and auditable. It helps in reducing transaction costs and eliminates various costs by automating actions [44].

Blockchain Benefits in Healthcare

This section investigates the benefits of blockchain within the context of healthcare. The literature on the blockchain technology provides evidence for the blockchain to overcome several shortcomings of the existing healthcare system. Blockchain technology characteristics enable effective management and exchange of patient's records.

Blockchain technology characteristics include: decentralization of the patient’s records storage, immutability, security, consensus, smart contracts, and irreversibility. Decentralization of the patient’s records provides a universal source of truth that enables interoperability and efficiency [69] [77]. Blockchain helps to eliminate the need for data reconciliation across all parties involved in the transaction, which would save in cost efficiency performance.

Blockchain has the potential to achieve HIPAA compliance [77] [78]. Blockchain facilitates access control for health information exchanges and allows patients greater ownership of their medical information and secure transfer of their patient records [17] [77]. Blockchain allows access to essential and sensitive patient data only for authorized users [79]. Blockchain solutions can create a life-long and longitudinal patient health record [80] [76]. Blockchain allows for the aggregation of health data without the need to move all the data to a central database or one single location. Patients have ownership of their own data and can grant access to whom they wish to share with. Patients have the right to own their own health records, while healthcare providers in the current EHR have the ownership of that records [17] [78] [76].

Distribution of the patient records and the immutability allow for greater security of patient’s records and integrity of the data [68] [71]. Data integrity is a crucial part of healthcare as the lack of information or incorrect information needed for patient care poses an issue in the existing healthcare system [68].

Blockchain minimizes the ability of unauthorized users to derive personal health information [77] [79]. Blockchain is a distributed ledger. Immutable transactions help ensure data integrity. Encryption of patient data enhances data security across the network. In the existing healthcare information systems, patient data is subject to data breaches or at high risk of vulnerability to failure, and corruption happens regularly [77] [81]. Some patients withhold information from their healthcare providers due to concerns about the security and privacy of their records [81]. Thus, data security stands at the top of the blockchain benefits.

Blockchain design allows the healthcare system to overcome the fragmentation problem of scattered health data across the healthcare systems. A study on a sample size of 8,774 on the current state of EHR shows that around 40% of physicians consider EHR design and interoperability as primary sources of dissatisfaction [12]. It is estimated that less than 10% of healthcare organizations regularly share medical information with providers outside of their organization [13]. The lack of interoperability and limited data sharing between the healthcare storage systems makes it difficult to transmit, retrieve, clean, and analyze data [13].

Blockchain technology allows for better interoperability. The blockchain health system facilitates medical research which in turn allows better understandings of healthcare and scientific discoveries; allows needed collaboration between different healthcare organizations; and strengthen regulations and standards that improve healthcare [77]. Data is shared without compromising the security of protected health information [69]. The balance between privacy and accessibility of EHR is ensured. Blockchain overcomes the multiple standards concern among different EHR systems by allowing access through APIs; which enable standardization of data formats and results in better interoperable healthcare systems [77].

Smart contract functionality on the blockchain helps automate many actions that eliminate human judgment and errors. Blockchain helps in tracking state transitions like viewership rights. Blockchain helps reduce the cost of actions that require human capital to perform, such as; billing or new record creation in a system [68]. Smart contracts can automate many tasks that are traditionally labor-intensive [44] [54]. Forecasts suggest that implementation of blockchain in retail banking would result in a 30% reduction in banking-related jobs in the U.S. and Europe over the next decade [82]. Smart contracts have the potential to bring a considerable amount of cost reduction in many industries [44].

Blockchain technology can serve as a platform to enable better utilization of different advanced technologies, such as: big data analytics, smart contracts, and artificial intelligence [46] [76]. Blockchain enables better clinical research and services [17]. Blockchain has a positive and significant impact on the three pillars of analytics: data, model, and computation [17]. Blockchain offers scientists access to a massive amount of raw data that would produce impactful discoveries in the medical field without compromising the patient's privacy [74] [77].

Blockchain allows higher utilization of artificial intelligence (AI) analysis technologies due to the availability of data in blockchain [71]. Blockchain technology is an attractive technology for research and development as it enables computer learning and AI [23]. Utilization of the blockchain technology to manage, store, and exchange patient data is able to offer a platform to engage in and benefit from the technologies, such as: AI, and analytics.

There are many other benefits that can be derived from blockchain. Blockchain technology can provide benefits such as: disintermediation, industry collaboration, and derive new business models [71] [67]. According to more than 45% of 588 respondents, the top three leading advantages of adopting blockchain in healthcare are disintermediation (eliminating nonvalue generating processes), heightened data security and integrity, and process automation via smart contracts [72].

Recovery contingencies are unnecessary due to the nature of blockchain technology as a decentralized system – every participant has the same copy as well as the immutability of the records [83]. Blockchain technology could save government and industry billions of dollars [83], provide a new healthcare delivery models, help address fraud and abuse activities, facilitate process and complexity of various healthcare activities [78] [67] [84], and has the potential to enhance collaboration, trust, traceability [80].

Joining a blockchain network or consortia could bring benefit to the healthcare industry in general, and healthcare organizations in particular. Joining a blockchain network is believed to bring costs down, accelerate learning, share risk, increase blockchain adoption, and influence standards [67]. Table 4 summarizes the significant benefits of blockchain technology.

Table 4. Blockchain Benefits

Benefits		Reference
Transparency	Blockchain is a more transparent system due to the immutability of the stored data. Blockchain is an immutable system where once a transaction is verified and recorded, it cannot be deleted or altered.	[43] [44] [46] [54] [63] [71] [80] [67] [84] [10][65] [76] [85]
Data Integrity	Blockchain ensures data integrity. Distribution of the patient records and the immutability allows for greater security of the records and integrity of the data. It ensures that no centralized authority exists that can be vulnerable and at the risk of security attacks.	[86] [54] [63] [81] [68] [77] [79] [83] [78]
Automation	Smart contracts allow for the automation of various tasks that traditionally require intensive labor forces. It eliminates human judgment and errors. It helps reduce transaction costs and eliminate certain costs by automating certain actions. It results in improved efficiency, cost-saving, and reduction of human errors.	[54] [82] [44] [68] [72] [78]
Cost Saving	As a result of it is nature as a decentralized database, it is suggested that blockchain can greatly save costs and improve efficiency. It lowers transaction costs.	[44] [54] [75] [46] [87] [83] [78] [67]
Security & Privacy	Security is in the heart of the blockchain. Blockchain provides a well-advanced level of security and encryption capabilities. It provides encryption mechanisms that minimize potential security breaches. Also, depending on the sensitivity of the data, on-chain and off-chain storage is permitted.	[46] [54] [48] [49] [74] [88] [83] [78] [67] [77] [79] [81] [65] [89] [76] [66]
Enabling Platform	Blockchain technology can serve as a platform to enable better utilization of different advanced technologies such as big data analytics, smart contracts, wearables, and artificial intelligence.	[46] [17] [85]
Efficiency	Blockchain improves operational and technical efficiency. Efficiency is achieved by the ability of blockchain to provide an immutable and distributed record-keeping validated by community consensus. It helps to eliminate the need for data reconciliation across all these parties, which would save massive efficiency and money.	[49] [75] [46] [69] [77] [83] [76]
Interoperability	Interoperability is improved due to the decentralizablility of the system. Blockchain facilitates the access control for health information exchange and allows patients greater ownership of their medical information and secure transfer of patient records.	[74] [69] [77] [17] [77] [79] [78] [80] [90]
Complete Health Record	Blockchain solutions can create a life-long and longitudinal patient health record.	[80] [90] [76] [90]
Patient-Centered	Patients have the right to own their health records while healthcare providers in the current EHR have full ownership of those records. It provides enhanced patient-centered healthcare by engaging patients in their health care.	[17] [78] [65] [76] [85]

One way to demonstrate the power of blockchain technology is through exploring its various benefits based on its components. Table 5 shows the blockchain components and benefits.

Table 5. Blockchain Components and Benefits

Component	Benefit
Distributed	• No single point of failure • Interoperability • Solve data silos issue • Efficient • Reducing reliance on costly intermediaries • Industry collaboration • Improved security
Immutability	• Traceability • Data integrity • Transparency and auditability
Smart contract	• Facilitate the execution of business tasks. • Reduce human errors

2.5.2.3 Challenges and Consideration of the Blockchain Technology Adoption

This section introduces the challenges, drawbacks, and consideration of blockchain technology adoption. It looks at the challenges facing blockchain technology in general, and blockchain within the healthcare industry in particular.

Blockchain may face some technological, governance, organizational, and societal challenges in its way to revolutionizing businesses [43]. Technical challenges surrounding blockchain include [46] [81] scalability, which is a considerable concern. As the number of blocks increases, the need for more storage capacity is needed. Scalability includes the ability of the blockchain system to process transactions in a timely manager. Blockchain is believed to be very safe as users only make transactions with generated addresses rather than using their real identity. Users could generate many addresses in case of information leakage. However, blockchain cannot guarantee transaction privacy since the values of all transactions and balances for each public key are publicly visible [46]. In the case of a private or consortium only a single of selected trusted users will have access to the data.

For efficiency and control:

- Centralized systems are often easier to manage, easier to scale, and faster to operate than the blockchain system [49].
- The replication and broadcasting of all transactions are computationally and network intensive, which would result in increased power consumption and cost [49].
- The verification of the transactions is done by the network participants that would slow the operations.

Due to the distributed nature of the blockchain, there is a tension between privacy and transparency [63]. Privacy can be achieved in the blockchain with a higher degree than the centralized system. Transparency and public verifiability pose a risk on the privacy on the blockchain [63]. Private Blockchain and Consortium Blockchain achieve higher privacy levels than Public Blockchain. Blockchain is an emerging technology and the current models of blockchain are: immature, can be challenging to scale, poorly understood, and unproven in mission-critical [18] environments. However, the technology is maturing very fast and implementations are moving quickly beyond the pilot and proof of concept phase [19] [67]. There is a lack of standards where many blockchain vendors do not offer compatible software [22]. Ivan believes that the clarity of stakeholders who seem motivated to implement blockchain is lacking [81]. Another challenge facing the widespread implementation of blockchain is a lack of financial incentives for entities to build and participate in a large network blockchain solution [91]. Hogan indicated in his research that blockchain implementation is difficult due to: immature technology, insufficient skills, regulatory constraint, lack of executive buy-in, lack of clear ROI, and insufficient business cases [73].

Challenges and Considerations in Healthcare

Despite the significant benefits blockchain seems to bring to the healthcare industry, various challenges and considerations should be addressed to ensure acceptance and diffusion. In this section, I touch upon the challenges and considerations expected for widespread adoption of blockchain technology in the healthcare sector. Challenges vary from technical, legal, business, trust [17], and socio-technical issues [92].

Costs are associated with the implementation and use of the blockchain to manage and share patients records, such as: initial cost, cost of joining the network, cost of overcoming the standardization issues, cost of operation, cost of sharing data, cost of following regulatory guidelines, and cost of maintenance [17] [79] [93] [39] [80] [94].

These costs include the cost of putting the blockchain into production and getting market participants to join the blockchain network. Cost of data exchange includes associated costs of confirming transactions. Costs of confirming transaction involves electricity consumption and capital equipment costs [93]. Due to the scarcity of blockchain implementations and use cases within healthcare, there is cost uncertainty associated with blockchain implementations.

Getting the market participants to join the blockchain network [69] [17] is another challenge. Joining the network requires the market participant to give up control of their data to the market forces. Without a central authority, data can be synced between providers, which solves the need for reconciliation concerns. It is hard, expensive, and time-consuming to reconcile data into one central point. A blockchain between these providers, that is a central authority, power is removed and the same agreed upon copy of the data is shared. All the participants have equal power over the shared data. Efforts to from the blockchain network will be required to convince healthcare providers to join.

One of the significant concerns associated with the implementation of blockchain technology in healthcare is the scalability issue [17] [93] [80] [95] [96] [21]. Determinations of the number of transactions that can be accepted and processed per second will need to be considered. Bitcoin, the first blockchain application, can only process seven transactions per second. IBM developed a blockchain solution that has achieved 3,500 transactions per second [97]. Transactions can be stored on the chain, and other transactions off the chain, in the case of Private Blockchain to reduce the load on the blockchain and improve the performance and scalability.

Sharing data across the system to healthcare participants will require storage capacity expansion to accommodate the "same version of the truth" among all participants. The transaction volume and size of the clinical data increases exponentially through time and with the increase in using modern technologies [39].

Even though the scalability of the blockchain is a significant challenge, many solutions have been proposed to overcome this shortcoming. Healthcare organizations can store part of the data off-chain while other data can be shared using smart contracts. The stored off-chain data will have a link to the blockchain, and healthcare organization can retrieve off-chain data only when needed. That is to say that sensitive information could be stored off-chain for security and privacy reasons.

Regulation uncertainty surrounding the blockchain is another issue that should be considered [17] [80]. In healthcare systems, blockchain diffusion is moving slower as healthcare data is tied to governmental regulations. Essential to be addressed by entities are: Health Information Portability and Accountability Act (HIPAA), data privacy acts, general data protection rules, and other protected health information policies. Healthcare related blockchain initiatives and projects must be aware of and responsive to continually shifting regulatory landscapes. [73]. A clear governance structure should be in place to manage the network involving multiple disparate parties.

Healthcare organizations should understand how blockchain works. The awareness of the blockchain technology potential to disrupt the healthcare system and solve many of the current healthcare issues should be understood by the different levels of the healthcare organizations from top management down to IT departments [69] [79] [21]. A survey of 1,392 medical practice administrators and executives examining awareness of blockchain technology, showed only 16 percent know about blockchain technology. Of that 16 percent knowing blockchain technology, 43 percent stated they knew it is also about information sharing [98]. In a survey of around 3,000 physicians, on the readiness of the blockchain technology for healthcare, about half of the physicians stated that they are not aware of the blockchain technology [99].

Companies consider activities to enhance their knowledge regarding blockchain technology [67]. The top activities cited by designated "top organization's" executives were: providing current employee with in-house courses (54% of the 1,300 executives), recruiting (52%), online training (51%), external in-person training (49%), acquisition (39%), mentoring (34%), and laboratory (20%).

The lack of real-world applications of blockchain technology in managing and sharing patient records hinders its widespread adoption. The maturity of the technology and availability of use cases are also significant factors in holding many healthcare organizations from adopting such innovative technology [69] [92]. A survey of 200 healthcare executives in 16 countries found that more than 50% of those surveyed cited immature state of the blockchain, insufficient skills, and regulatory constraints as the top-3 barriers to adopting blockchain technology in healthcare [73]. Gradual implementation should be encouraged to facilitate the acceptance and realization of its benefits.

EHR systems use inconsistent standards that make it harder for data exchange. Standardization requires specific considerations in the implementation phase [100] [80] [74] [101] [54] [102] [101] [103]. Various frameworks have been proposed to overcome standardization issues that include: using APIs, implementing EHR semantics, and format checking methods [100]. In the implementation side, there is a lack of agreed-upon standards among vendors and clients thusly many blockchain vendors do not offer compatible software [22]. OmniPHR is a blockchain technology implementation framework that requires data to comply with a set of standards; otherwise, data cannot be stored in the blockchain network [96]. Due to the blockchain technology immaturity, setting up standards may hinder blockchain development [54]. Standardization would not be problematic with small scale implementations as it would on the large-scale implementations [54]. Overall, standardization ensures interoperability.

There are internal and external challenges influencing the adoption of blockchain technology that were identified by Meyer and McCraw [72]. The top internal barriers include identifying cost-benefits of use cases and understanding blockchain technology and its most useful applications. The top five external roadblocks to blockchain adoption are: scalability/latency, privacy and security, interoperability between various blockchains, legal and regulatory issues, and working with partners/ecosystem members.

The number of blockchain consortia is increasing. The number of active blockchain consortia across industries has rapidly increased from 28 in 2017 to more than 60 [97]. Nearly half the respondents believed that their organization will need additional expertise in legal, business strategy, and cybersecurity areas to fully realize blockchain potential [72]. Kshetri stated that the main barriers to introducing blockchain might be educational rather than technical [21]. The following Table 6 summarizes the significant challenges and considerations related to the adoption of blockchain technology.

Table 6. Blockchain Adoption Challenges and Considerations

Challenges and Considerations		Reference
Scalability	One of the major concerns associated with the blockchain implementation in healthcare is the scalability issue. The transaction volume and size of the clinical data increases exponentially through time and with the increase in using modern technologies. Storing data On-chain and Off-chain could be a solution.	[39] [86][46] [72] [78] [17] [80] [81] [83] [84][93][95] [96][104]

Privacy	Due to the distributed nature of the blockchain, there is a tension between privacy and transparency. Some authors believe that blockchain cannot guarantee transactional privacy since the values of all transactions and balances for each public key are publicly visible. However, depending on the sensitivity of the data, on-chain and off-chain storage is permitted to ensure more security and privacy.	[46] [63] [72] [104] [67] [86]
Cost	Different costs are associated with the implementation and use of the blockchain to manage and share patient records such as initial cost, cost of joining the network, cost of overcoming standardization issues, cost of operation, cost of sharing data, cost of following regulatory guidelines, and cost of maintenance. Also, the replication and broadcasting of all transactions are computationally and network intensive that would result in increased power consumption and cost.	[39] [49] [17] [79] [80] [83] [93] [97]
Technology Immaturity	Furthermore, blockchain is an emerging technology, and the current models of the blockchain are immature, can be difficult to scale, poorly understood, and unproven in mission critical.	[18] [54] [67] [73] [105]
Clarity and support of stakeholders	There is a lack of clarity of stakeholders who seems to be motivated to implement blockchain as well as the support of various influencing stakeholders.	[73] [81] [105]
Incentives	Another challenge facing the widespread implementation of blockchain is the lack of financial incentives to build and participant in a large network blockchain solution.	[83] [85] [91]
Skills	There is a lack of enough skills required to build and maintain the blockchain.	[67] [73]
Regulatory Constraint	Regulation uncertainty surrounding the blockchain is another issue that should be considered. Regulation involves the extent to which the blockchain can comply with the existing security and privacy regulations. Also, the technology is new and immature, which makes it hard to predict its regulatory future.	[86][67] [72] [73] [17] [80] [83] [84] [97]
lack of clear ROI	Many healthcare organizations are waiting for a proven and clear return on investment measurements to move on in adopting blockchain solutions and join a network.	[67] [73]
Insufficient business cases	The lack of real-world applications of the blockchain technology in managing and sharing patient records hinder its widespread adoption. The maturity of the technology and availability of use cases are significant factors in holding many healthcare organizations from adopting such innovative technology	[69] [73]
Awareness	The awareness of the blockchain technology potential to disrupt the healthcare system and solve many of the current healthcare issues should be understood by the different levels of the healthcare organizations from top management down to IT departments.	[69] [79] [98] [99]
Building the network (ecosystem)	Another challenge is getting the market participants to join the blockchain network. There have to be enough efforts to get healthcare organization to join the network as well as for them to work with partners/ecosystem members	[69] [17] [72] [83] [97]
Standardization	EHR systems use different standards, which makes it harder for data exchange. Standardization requires certain considerations in the implementation phase as well as there is a lack of agreed-	[54] [80] [74] [83] [85] [22] [96] [97] [100]

	upon standards among vendors and clients where many blockchain vendors do not offer compatible software.	[101] [102] [104]

Selected Literature on the Blockchain Challenges and Considerations in Healthcare

This section presents selected literature that investigates blockchain technology adoption challenges and considerations as well as providing evidence of the need to explore the blockchain technology adoption comprehensively, taking into consideration multiple perspectives and factors:

1. Clohessy et al. explored blockchain technology adoption considerations from technological, organizational, and environmental factors using innovation theory [105]. The main blockchain benefits identified and discussed in the research are anonymity, immutability, and transparency. The top technological factors influencing the adoption of blockchain technology include: perceived benefits, complexity, compatibility, data security, maturity, and relative advantage. Organizational considerations encompass: organizational readiness, top management support, and organizational size. The environmental considerations include: regulatory environment, market dynamics, industry pressure, and government support. The research advances the discussion on the organizational factors as believed to be the most significant drivers of adoption. Top management support is significant as it may involve activities such as: new regulatory requirements, the acquisition of new resources, the integration of resources, and the development of new skills and competencies. The study concludes that there is a high association between the organization's adoption and top management support. The second organizational

factor is Organizational Readiness (OR). OR involves the availability of specific organizational resources to adopt blockchain technology. The OR encompasses the human resources, financial, and infrastructure facets. The facets ensure cooperation and acceptance of: management, employee, and results in more significant effort and engagement in order to initiate the OR change. The final organizational factor is organizational size. Size is considered an essential determinant of blockchain adoption. While it is believed that large organizations are more likely to adopt blockchain than small companies, the research shows that due to the unique characteristics of the blockchain technology and the flexibility and adaptability of the small organization, the smaller organization has been more likely to adopt blockchain.

2. McGhin et al. investigated the blockchain literature and identified both different and unique requirements for blockchain technology that have an impact on the healthcare industry [104]. These requirements are related to authentication, interoperability, data sharing, transfer of medical records, and considerations for mobile health. These aforementioned requirements are the current issues within the healthcare industry. The authors list multiple blockchain limitations and issues, such as: lack of standardization, decentralized storage and privacy leakage, key management, and scalability and IoT overhead.
3. Schatsky et al. published a report, as part of Deloitte Insights, exploring five barriers to adoption that companies should consider and address before adopting blockchain [97]. Firstly, blockchain can be slow. Companies should work to develop a

mechanism to increase the transaction speed. Secondly, there is a lack of standards. The lack of standards could hinder the interoperability between ledgers. The third barrier is blockchain solutions are complex and costly. The fourth barrier is regulatory issues. Nearly two in five blockchain-savvy executives cited regulatory issues as a barrier to more significant investment in blockchain technology. Companies should collaborate with policymakers to enhance the understanding of the technology and create a robust regulatory framework. The fifth barrier, is the challenge in getting organizations to work together to advance shared objectives of the technology. Effort in creating an ecosystem of partners includes defining use cases, setting standards, developing infrastructure and applications, and operating the blockchain network.

4. Batubara et al. conducted a systematic literature review to explore the challenges of blockchain technology adoption for e-government [84]. The authors classified the barriers into perspectives of: technological, organizational, and environmental. Technological barriers include: security, scalability, and flexibility; organizational barriers involve: acceptability and governance models; and environmental barriers are: the lack of legal and regulatory support. Despite the various challenges facing the adoption of blockchain technology, the research authors discussed the potential of blockchain technology to: improve transparency, prevent fraud, and establish trust in the public sector [84].
5. Deloitte conducted a survey of more than 1,000 senior executives in seven countries in 2018 to investigate where blockchain is headed [71]. Respondents surveyed had a

broad understanding of blockchain technology and their organizations' blockchain investment plans. Around 60% of respondents indicated that their organizations are planning an investment in blockchain at amounts of one million dollars or more within the next calendar year. Respondents indicated a positive attitude toward the technology, in terms of: scalability, ecosystem, business case availability, and improving their competitive advantage. This survey explored the organization's barriers that are hindering significant investments in blockchain technology. Respondents indicated several barriers such as regulatory issues (39% of respondents), implementation challenges (37%), potential security threats (35%), uncertain ROI (33%), and lack of in-house skills/understanding (28%).

6. An earlier report by Deloitte explored five implementation challenges [83]. These challenges include: scalability constraints, data standardization and scope, adoption and incentives for participation, cost of operating blockchain technology, and regulatory considerations.
7. IBM published a report highlighting the technical challenges that might hinder the adoption of blockchain technology [78]. Scalability is a significant challenge. Additionally, the integration of the blockchain technology within the corporate legacy systems, and systems of record, are challenging tasks that pose a roadblock in the widespread adoption of blockchain.
8. The IBM Institute for Business Value conducted a survey of 200 healthcare executives in 16 countries to explore blockchain technology adoption. The study showed that more than 50% of respondents cited: immature state of the blockchain,

insufficient skills, and regulatory constraints as the top-3 barriers to adopting blockchain technology in healthcare [73]. Nearly 16% of respondents reported that they are expecting to have more commercial blockchain solutions, at scale, in 2017. Those same 16% expect a peak in the number of projects between 2018 and 2020.

9. Another report published by Deloitte [80] has addressed the challenges facing blockchain technology in the life sciences and health care industries. Challenges addressed include the tremendous amount of effort to ensure involvement of multiple stakeholders, such as: healthcare organizations, health plans, and individual governments. Scalability, standardization, incentives, cost, and regulations are among other challenges facing blockchain adoption.

The following table 7 shows a summary of the selected literature on the challenges and considerations related to blockchain technology adoption.

Table 7. Selected Literature on the Blockchain Adoption Challenges and Considerations

Study	Challenges/Considerations	References
Blockchain Adoption: Technological, Organizational and Environmental Considerations.	Top management support, organizational readiness, and organizational size.	[105]
Blockchain in healthcare applications: Research challenges and opportunities	lack of standardization, decentralized storage and privacy leakage, key management, and scalability	[104]
Blockchain and the Five Vectors of Progress	transaction speed, lack of standards, complex and costly projects, regulatory issues, and getting organizations together.	[97]
Challenges of Blockchain technology adoption for e-government: a systematic literature review	Technological barriers include security, scalability, and flexibility; organizational barriers involve acceptability and governance models, and environmental barriers are the lack of legal and regulatory support.	[84]
Breaking Blockchain open Deloitte's 2018 global Blockchain survey	regulatory issues, implementation challenges, potential security threats, uncertain ROI, and lack of in-house skills/understanding.	[71]
Blockchain: Opportunities for health care	These challenges include scalability constraints, data standardization and scope, adoption and	[83]

	incentives for participation, cost of operating blockchain technology, and regulatory considerations.	
Blockchain: The Chain of Trust and its Potential to Transform Healthcare – Our Point of View	Scalability and the integration of blockchain with the corporate legacy systems	[78]
Healthcare rallies for Blockchains Keeping patients at the center	Immature state of the blockchain, insufficient skills, and regulatory constraint.	[73]
Blockchain to Blockchains in Life Sciences and Health Care	The amount of effort to ensure the involvement of multiple stakeholders such as healthcare organizations, health plans, and individual governments. Scalability, standardization, incentives, cost, and regulations are among other challenges facing the blockchain adoption.	[80]

2.5.2.4 Current State of Blockchain Projects

Blockchain projects can be separated into three categories. The first blockchain project category is "Pure R&D." Pure R&D refers to learning and understanding the process of developing a blockchain system. The second blockchain project category is immediate business benefits. This covers two types of projects: learning the technology, and delivering a system that can be deployed. The third category is developing a blockchain solution for the long-term transformational potential. This is where the real value of the blockchain is realized regarding how it can transform the business and industry [24].

HIMSS surveyed 160 healthcare stakeholders, in 2018, to examine their interest in blockchain technology [106]. The results of the survey showed that 45 percent believe that their organization are still investigating or learning about blockchain. Nearly37 percent indicated their organization had no current ongoing blockchain discoveries. Six percent are building business use cases and securing support. Nearly half, of six percent building use cases and securing support, plan to do so within the next two years. Three percent are already actively pilot testing blockchain use cases. Non-providers (which includes payers and consultants) are two times more likely than providers to do so (within the next two years).

Blockchain is an emerging technology. Adoption and implementation are complex. Adoption and implementation take into account various internal and external factors. Investments in blockchain startups in 2016 were estimated to be over $1.4 billion [44]. Blockchain business challenges are most likely to be more significant than blockchain technology challenges [20]. Recent reports show that a high number of blockchain projects, in terms of goal and timeline, are either: shutting down, or scaling back [22]. It is estimated that 90% of blockchain projects will not survive to be operational [22].

Forrester tracked 43 blockchain projects, that proposed blockchain as revolutionary in their respective industries, and concluded that none of these projects had achieved their full implementation objectives [23]. According to the VP of the Forrester, “In 2018, we expect to see a number of projects stopped that should never have been started in the first place.” [24]. Deloitte conducted a survey of more than 1,000 senior executives in seven countries to investigate where blockchain is headed [71]. Respondents had, at least, a broad understanding of blockchain technology and their organizations’ blockchain investment plans. Nearly 63 percent of health care organization respondents stated that they are planning to invest more than one million USD over the year of 2018.

Data from GitHub, as the world's largest community of software developers, gives an overall depiction of the current state of the blockchain software development. The number of GitHub blockchain related projects published on GitHub since 2009 has grown significantly. GitHub blockchain projects are averaging more than 8,600 new projects per year. Nearly 27,000 new projects, only in 2016, and many of those projects being developed by organizations. The percentage of GitHub projects being developed by organizations has grown from 1% in 2010 to 11% in 2017 [107]. The number of blockchain communities on GitHub is estimated to be 772 [107].

In terms of success: considerable number of blockchain projects on GitHub either get abandoned or do not achieve a meaningful scale. Only 15% of the blockchain projects developed by organizations are active [107].

In the market: IBM and Microsoft have secured around 51% of the blockchain products and services market [22].

Current Frameworks and Prototypes

There have been many publications which have proposed different types of blockchain implementations. Implementations proposed are in the area of management of patient’s records, These publications also report on real world blockchain projects, and prototypes.

- Zhuang et al. implemented a private blockchain for HIE and persistent monitoring of clinical trials [47]. The blockchain solution is built to connect multiple EHR systems from different providers [47].

- Dubovitskaya et al. proposed a Permissioned Blockchain framework to manage and exchange the EMR data for cancer patient care. The researchers built the a prototype in collaboration with Stony Brook University Hospital [87]. The proposed implementation could provide significant values, such as: reduction in the turnaround time for EMR sharing, improvement in the decision making for medical care, and cost-savings [87]. This prototype is not currently in operations.
- Fan et al. proposed a blockchain-based health information management system, MedBlock, to manage patients' EMR [103]. The solution enables efficient EMRs access and retrieval. The solution achieves a consensus of EMRs without high power consumption or network congestion [103].
- Zhang et al. proposed a clinical data sharing blockchain framework, FHIRChain, to address technical interoperability requirements from the office of national coordinate [108]. FHIRChain is a smart contract, based solution, for exchanging health data using the standard FHIR. In this implementation, the clinical data is stored off-chain, and the blockchain stores encrypted meta-data which serves as pointers to the primary data source [108].
- Dagher et al. proposed a blockchain based framework utilizing the Ethereum blockchain platform for secure, interoperable, and efficient access to medical records by patients, providers, and third parties, while preserving the privacy of patients' sensitive information through smart contract and advanced cryptographic techniques [77].

- Hussein et al. proposed a blockchain-based data-sharing system to tackle the issues related to patient data privacy; due to the records being scattered across multiple healthcare institutions or during the data exchange [109]. The solution utilizes properties of blockchain, such as: immutability, and autonomy in order to sufficiently resolve challenges associated with access control and handle sensitive data, as well as; enhance system security and immunity to various attacks. The proposed solution allows verifying of users securely, and in a fast way. It also allows further accountability because all users on the blockchain network are already known, and blockchain creates a log of actions [109].
- Wang and Song proposed a secure electronic health record (EHR) system, based on blockchain technology; and attribute-based cryptosystem in order to achieve: confidentiality, authentication, integrity of medical data, and support fine-grained access control [110]. The proposed solution facilitates the management of the EHR systems, as well as; blockchain techniques which were used to ensure integrity and traceability of medical data [110].
- Chen et al. proposed a blockchain framework; by designing cloud storage for use in patients, sensitive medical records, data sharing[111]. The framework uses a digital archive that has access control rights to its owners' information. The proposed framework does not rely on a third-party or intermediary with the power to affect the processing [111].
- Guo et al. proposed a blockchain solution to introduce an attributed-based signature scheme to guarantee the validity of EHRs: with multiple authorities, and without a

trusted single or central authority.[112]. The proposed solution guarantees the immutability of information while preserving patient privacy [112].

- Roehrs et al. proposed OmniPHR, a distributed blockchain-based architecture for Personal Health Records to solve the issue of patient health records scattered across disparate healthcare institutions. The architecture also allows healthcare professionals access to a unified and a complete health record [96]. The proposed solution promotes interoperability and a unified view of patient records through the distributed ledger technology. The architecture puts the patient in the center of the process. Challenges with OmniPHR are that data must comply with the OmniPHR standard, the user has to authorize all access requests, and there is potential data duplication [96].
- Xia et al. proposed a Blockchain-based solution, MeDShare, to address the issue of medical data sharing among healthcare providers that store medical data in a trust-less environment [113]. MeDShare provides data provenance, auditing, and control for shared medical data, among large entities, in cloud-based environments. MeDShare monitors parties that access the medical data for malicious use. Malicious use entails any entity that tries to access the data without proper permission. Exchanged data and actions performed in the blockchain network are recorded in a secure and tamper-proof manner. MeDShare blockchain utilizes smart contracts, and access control mechanisms, to monitor transactions, and control access permissions, for authorized entity use. The goal of MeDShare is to provide cloud service providers, who store medical data, the ability to achieve data provenance and auditing while sharing

medical data with other entities in the medical community, all while ensuring data privacy [113].

- Gem Health Network has developed an Ethereum based blockchain solution to solve the problem of data sharing [114]. The blockchain network allows healthcare providers to access healthcare information in a decentralized way removing the need for a central exchange intermediary. This solution allows for medical information to be: relevant, transparent, properly permissioned, so that only users with rights have real-time access to the medical records [114]. The solution enables better interoperability and information exchange in order to enable better healthcare decision making [114].
- MedRec is a decentralized, working prototype, blockchain solution that was designed to handle EMRs [88]. MedRec is among the most popular prototypes. The solution was incubated at Massachusetts Institute of Technology (MIT) labs. The prototype enables patients to access comprehensive and immutable medical information across healthcare organizations. The MedRec blockchain-based solution manages: authentication, confidentiality, accountability, and data sharing of patient sensitive information. MedRec is made up of smart contracts implemented through the Ethereum blockchain which allows for automation and tracking state transitions, such as: change in viewership rights, or addition of a new record. The prototype associates a medical record with viewing permissions and data retrieval instructions. The framework has two limitations: one, it does not address the security of individual

databases, and two, it does not attempt to address the issue of having an emergency patient.

- Yue et al. proposed a blockchain-based smartphone app, Healthcare Data Gateway (HGD), that would enable patients to own, control, and share their data efficiently and securely without violating patient privacy [115]. The app would facilitate making legal and regulatory decisions related to collecting, storing, and sharing patient data simpler [115].

Based on the study of the previous projects and prototypes, we can observe that many of the proposed blockchain frameworks are based on Ethereum or Hyperledger platforms [116]. MedRec and Patientory blockchain frameworks proposed the use of a blockchain-based on the Ethereum platform for management of health information applications [116]. Hyperledger platform has been used for: oncology clinical data sharing framework, mobile healthcare application, and medical data storage or access applications [116]. Blockchain technology has proven its capability to serve as the patient's records management platform. Blockchain can be utilized for the management and exchange of patient's records. Organizational, regulatory, financial, and social challenges have to be addressed to take full advantage of blockchain technology.

It can be observed from the above list of projects and prototypes that the most suitable and utilized implementation is the Private Permissioned blockchain implementation.

2.5.2.5 Healthcare Use Cases

Blockchain technology has many applications in the HIT space. The use cases include: patient data management, supply chain management of medical goods, prescription management, billing claims management, and analytics [17] [79]. In the pharmaceutical space blockchain technology can be used for drug traceability, while complying with drug regulations and acts, from manufacturer to consumer. Blockchain technology, eliminates fraudulent data modifications and interoperability, which are a concern in clinical trials.[79].

One of the most promising use cases is the utilization of blockchain as the underlying infrastructure for: health data management, Electronic Health Records (EHR), and Health Information Exchange (HIE) [117]. Medical records solutions are among the most popular applications for blockchain in health [73]. Blockchain data management applications include: global scientific data sharing for R&D, data management, data storage (cloud-based applications), and EHRs [74]. Blockchain could be used to store: the entire patient's record, hashed pointers to medical records and permissions, or hashes of references. The query link information is sent in a private transaction over HTTPS [77].

2.6 Healthcare System Issues and Blockchain

This section introduces the current issues in the existing healthcare system and how the blockchain technology contributes to solving such issues. The annual report submitted to the U.S. Congress on the adoption of a national system for the electronic use and exchange of health information for the year 2018 highlighted critical barriers to interoperability that continue to limit the access and use of electronic health information.

These barriers include: technical, financial, and trust barriers [118]. Technical barriers include: lack of standard development, data quality, and patient and healthcare provider's data matching. Financial barriers include: costs of developing, implementing, and optimizing HIT. Optimizing HIT includes meeting frequently changing requirements of health care programs, the lack of sufficient incentives for sharing information between health care providers; and trust barriers (including legal and business incentives) to keep data from moving [118].

2.6.1 Healthcare Waste

Healthcare systems are unable to mitigate waste through utilization of existing technologies, or through adoption of innovative systems. Studies have examined waste in the healthcare system. Smith et al. investigated sources of excess costs in U.S. healthcare in 2009 [119]. They classified waste in U.S. healthcare into six domains: unnecessary services ($210 billion), excess administrative costs ($190 billion), inefficiently delivered services ($130 billion), prices that are too high ($105 billion), fraud ($75 billion), and missed prevention opportunities ($55 billion) [119]. A study conducted by Kelley, in 2009, estimated U.S. healthcare waste totaling $700 Billion [4]. The amount of waste in the U.S. healthcare system is estimated to be 5% of GDP [120]. Other studies indicate that about 20%, equivalent to $1.2T of the health spending in the OECD countries, is considered to be waste [121]. It is estimated that the amount of waste in the total U.S healthcare expenditure is around 20% [5]. The waste includes: overtreatment, failures of care coordination, failures in the execution of care processes, administrative complexity, pricing failures, and fraud and abuse [5]. Medical errors cost the U.S. healthcare system around $17 to $29 billion annually. Full utilization of HIT should result in a cost-saving of around $80 billion [122]. Lyu et al .surveyed 2,106 physicians examining their perception of overtreatment as a cause of preventable harm and waste in healthcare problems [14]. The study indicates that 20.6% of all medical care was unnecessary. Sources of waste include: prescription medications (22%), tests (24.9%), and procedures (11.1%) [14]. Reasons for overtreatment include: fear of malpractice (84.7%), patient pressure/request (59.0%), and difficulty accessing medical records (38.2%) [14]. Technology advancements have helped in reducing waste rate through utilization of computerized systems.

EHR helps to avoid unnecessary or duplicated tests or labs. One study found that such a computerized system helps in blocking about 11,790 unnecessary duplicate test orders in just two years. Those tests would have cost around $183,586 [30]. EHR helps reduce staff workload, which means low cost of overhead [31].

Blockchain technology helps in saving resources, such as; eliminating test duplication and controlling the waste in medications by allowing a complete history of the patient record. More than $2.1B is spent annually on inefficient and redundant tasks across the healthcare system to maintain provider data involving: hospitals, doctors, and health insurers[15] [16].

The Centers for Medicare & Medicaid Services (CMS) found that 52 percent of provider directory locations listed had at least one inaccuracy. Currently, the Synaptic Health Alliance; Aetna, Ascension, Humana, Multiplan, Optum, Quest Diagnostics, and UnitedHealthcare formed a group to implement a Permissioned Blockchain solution to improve accuracy of the provider data. The solution will allow members to view, input, validate, update and audit non-proprietary provider data within the network [16]. The proposed solution aims to reduce operational costs while improving data quality. The different characteristics of blockchain technology mentioned in a previous section control healthcare expenses and reduce healthcare wastes.

2.6.2 Administrative and Transaction costs

Spending on healthcare systems around the world is high and increasing annually. health care spending increased by 4.6% in 2018 to reach $3.6 trillion which accounted for 17.7% of U.S. GDP [29]. The growth of the hospital expenditures was 4.5% ($1,191.8 billion) in 2018 compared to 4.7% growth in 2017 [29]. It is estimated that 50% of healthcare costs are fraudulent, resulting from excessive billing or billing for non-performed services [123].

The Council for Affordable Quality Healthcare (a non-profit alliance of health plans and trade associations that intends to streamline the business of healthcare) published a report to investigate the transaction costs associated with medical claims [124]. A provider's manual processing of medical transactions is time-consuming. Manual processing is estimated to add five more minutes to each transaction compared to electronic transactions. Electronic transaction processing could save 40 minutes to up to an hour for a single claim.

Adoption of EHR resulted in lowering the administrative transaction costs [125]. These costs depend on the mode of conducting the transaction: fully electronic, partially electronic, or fully manual. Multiple costs are associated with sending or receiving a transaction. These costs may include: the cost of faxing the claim to the health plan, time spent processing the transaction, and labor. Cost and time are healthcare industry and providers potential savings. The estimated reduction in costs is $700 million [125]. The same report estimates that the combined medical and dental industries could save $12.4 billion per year with full adoption of electronic administrative transactions [125].

Claim costs include: eligibility & benefits verification, prior authorization, claim submission, claim status inquiry, claim payment, and remittance advice. It is estimated that cost-savings for medical transaction, if all the previous six transactions performed, for a single patient encounter would be $27.31 with full utilization of electronic workflow [125]. Claim status inquiry, prior authorization, and eligibility and benefit verification represent more than 80% of the transaction cost. It costs $3 more to process transactions manually than electronically [126].

Consumer convenience is an essential element of healthcare delivery. It is estimated that 65% of patients would consider switching healthcare providers for a better and smoother payment experience [126]. The percentage of patients preferring to pay by check (21%) is much lower than the percentage of the patients receiving paper statements (79%) [126].

Automation of actions that are proposed by smart contract functionality would reduce administrative costs by eliminating human capital and associated errors. Blockchain has the capability to reduce back-office data input, and maintenance costs, as well as; improving data accuracy, and security [90]. Blockchain technology eliminates the need for intermediaries. Eliminating intermediaries would reduce the administrative costs and time for providers and payers [123]. Blockchain technology is a decentralized system that would provide a cost-savings by eliminating the need for data reconciliation.

2.6.3 Health Information Exchange

The exchange of patient health information between healthcare providers is an essential "quality of care" factor. Many issues are related to the health information exchange including: interoperability, data integrity, accuracy, and data availability. Many healthcare organizations use types of EHRs that each use different standards. There are 26 different electronic medical records systems used in the city of Boston, each with its own language for representation and sharing data [127]. Patient records are scattered across multiple healthcare facilities, and thus sometimes patient records are not accessible when needed. Gandhi et al. claims that 63% of referring primary care physicians are dissatisfied with the current referral process due to the lack of timeliness of information and inadequate referral letter content [128].

Due to interoperability issues between healthcare providers, about 30% of tests are reordered, because; the results cannot be found or are of no benefit [11]. Efficiency issues result in resource waste. Another study indicated nearly 25% of U.S. patients reported that their test results and records had not been transferred from one provider to another in time for their appointment [119]. In many cases, physicians struggle to locate the necessary information to make informed patient care decisions during a visit (nearly81% of physicians confirmed) [129].

A study sample size of 8,774 on the topic of current state of EHR shows that around 40% of physicians consider EHR design and interoperability as primary sources of dissatisfaction [12]. It is estimated that less than 10% of healthcare organizations regularly share medical information with providers outside of their organizations [13]. Routine communication and updates of patient records between healthcare providers and primary care physicians is vital to building a current-updated patient record. Only 59% of the U.S. hospitals routinely electronically notified the patient's primary care provider upon emergency room entry in 2015 [130].

Data integrity is a crucial part of health information exchange. Data integrity means that data exchange should be correct: free of misleading information, and errors. Lack of information or incorrect information at time of patient care is considered a significant problem in healthcare, leading to medical errors and adverse events [92]. Nearly 80% of medical errors involve informational or personal mis-communication [131]. Issues include communication breakdowns among caregivers and patients, mis-information in medical records, mis-handling of patients' requests and messages, inaccessible medical records, and inadequate reminder systems [131]. Activities related to data preparation take up to 80% of data scientists' time and effort which includes data collection and cleansing [132].

Studies of current practices suggest there is a lack of appropriate mechanisms to manage and exchange patient records for better "quality of care." Among 2,106 physicians surveyed, in 2017, examining their perception of overtreatment, 38.2% indicated that difficulty accessing medical records is among reasons of overtreatment [14]. A study of 68 hospitals, in 63 pairs, on patient information sharing shows that information sharing between hospitals, with shared patients, tend to be worse than with other hospitals [133]. The study indicates "23% of respondents reported worse information sharing with their highest shared patient (HSP) hospital than with other hospitals.17% indicated better sharing with their HSP hospital, and 48% indicated no difference [133].

Another issue associated with the health information exchange is "information blocking.". The information blocking "occurs when persons or entities knowingly and unreasonably interfere with the exchange or use of electronic health information." (ONC for HIT, 2015) [134]. The information blocking could occur as a result of technical barriers beyond the control of the parties involved in the information exchange or due to the lack of appropriate coordination among parties involved in health information exchange (ONC for HIT, 2015) [134]. A study on information blocking among EHR vendors and providers surveyed 60 third-party HIE organizations in order to understand the extent of their engagement in information blocking and its common forms and occurrences [135]. The results show that 50% of the respondents indicate EHR vendors routinely engage in information blocking. An additional 33% reported an occasional involvement [135].

Issues associated with interoperability and health information exchange cost the healthcare system billions of dollars annually. Studies show that $77.8 billion of cost-savings, and net value, is projected annually with a fully interoperable and standardized HIE healthcare system [136]. Another study concluded that with a fully implemented HIE at a national level, a cost-savings of $3.12 billion annually, on average, for the healthcare sector could be achieved [137]. The use of well-implemented HIE has the potential to: save hospital resources, provide cost savings, decrease the length of stay (LOS), and provide improved quality of care [138] [139].

It is important to understand the need for integration of blockchain technology, into the current healthcare system, in order to manage and exchange patient records. Blockchain Technology allows data integrity and availability at the time of care to be ensured, and to provide safe and quality care. Blockchain technology holds promise to solve the interoperability issues in existing healthcare systems. The literature on blockchain technology suggests that blockchain technology, by design, can overcome the interoperability and health information exchange issue while meeting the requirements and standards of healthcare regulations. Blockchain can bridge the gap between different systems, with different standards, in scattered geographic locations [81]. Smart contract capability, that is only exposing the minimum amount of data necessary to satisfy a query, ensures an enhanced level of privacy and auditability [81].

There is multiple benefits blockchain technology provides for health information exchange. Blockchain removes the need for intermediaries since all participants will have access to the same shared data. Blockchain technology removes costs associated with the existence of the intermediaries, such as; the cost of transactions and data exchange. Blockchain technology provides a framework to enhance and support the integration of health care information across different healthcare parties. Blockchain provides real-time updates with new information distributed to all participants in the network. Blockchain allows for the smart contract to regulate and limit the access to specific data for selected participants [140].

2.6.4 Efficiency

Many technologies such as the fax machines have been in use in healthcare for decades. This technology has low-efficiency level compared to newer electronic systems. Of over 40,000 referrals examined, 54% led to scheduled specialty visits using a fax referral system, compared to 83% when implementing a web-based referral system [141]. Faxed referrals resulted in a lower rate of scheduled appointments due to technical issues, such as: referrals lost, not duly authorized, missing information, and taking too long to contact patients [141].

Miscommunication between healthcare providers, during care transitions, is considered a critical safety issue. Studies show that nearly 80% of medical errors involve miscommunication between providers during care transitions [142]. In the current healthcare system, healthcare organizations act as custodians or stewards of patient data which leads to inefficiency and delay in patient care [21]. Blockchain is believed to enhance operational and technical efficiencies as described in the section 2.5.2.2.

2.6.5 Complete Medical History

Patients records are scattered throughout different healthcare systems. EHR is not meant to create a lifetime record of the patient history [10]. Researchers have brought blockchain technology into the debate as a perfect solution to create one life-long record maintaining the EHR. Blockchain technology offers the ability to securely access the patient longitudinal health data across the distributed ledger [140].

2.6.6 Security

The security of the HIT resources, including patient records, is among the top priorities of healthcare providers and healthcare authorities. The current HIT practices do not comprehensively address security issues. Current infrastructure cannot guarantee privacy and security of patient data [21]. The number of individuals affected by protected health information breaches between 2014 and 2015 increased from about 1.8 million to about 111.9 million [8]. In 2018, six out of the ten top breaches were "Hacking/IT incident" type. [9]. The U.S. Department of Health and Human Services, Office for Civil Rights (OCR), built a breach portal. The breach portal contains a list of breaches, of unsecured protected health information, affecting 500 or more individuals [9]. Currently healthcare providers are solely responsible for maintaining security and integrity of patient records. Patient records can be challenging to recover. They ensure integrity of the data if a malicious entity alters the single copy record [77].

Healthcare organizations are responsible for data recovery, that is, having a security contingency plan in place. Organizations are subject to regulatory fines in case of health data being compromised. Without proper data storage and maintenance, patient data may be altered or even get lost. Blockchain technology provides a high level of "security by design" and is believed to provide an ideal solution to security issues. Blockchain enables transparency about medical treatments. Medical errors can be traceable to its error origin. Traceability enables healthcare systems: to track health records, to detect medical errors, wrong prescriptions, and reduces the cost of drug counterfeits [68] [17]. Blockchain removes the need for backup services and removes the need for having recovery mechanisms in place. Blockchain removes complex network of intermediaries that add considerable cost. Blockchain ensures efficient interoperability and exchange of patient records [17]. Recent reports show that the Department of Health and Human Services, Office for Civil Rights, received notifications of 351 data breaches, in 2018, of 500 or more healthcare records. The data breaches reported resulted in exposure of 13,020,821 healthcare records. In 2017, there were 359 data breaches, of 500 or more records, reported to OCR which resulted in exposure of 5,138,179 healthcare records [7].

In summary, the current problem with the existing systems revolves around: security, interoperability, costs, data integrity, data ownership (information blocking), complete medical history, and unnecessary procedures.

The following Table 8 presents issue types of the current healthcare system, and links the suggested blockchain solution to that issue.:

Table 8. Healthcare Issues and Blockchain Opportunities

Issue	Blockchain as solution
Security	The current system provides a low level of security capabilities. Blockchain provides a well-advanced level of security and encryption mechanism (minimize the potential hackability).
Interoperability	Distributed ledger (the same copy is distributed).
Data integrity	The data in the network are agreed upon and immutable. Blockchain enables a higher level of traceability and transparency.
Costs	Eliminate human errors and costs by the automation of intensive human actions, no need for frequent backups, and reduce back-office data input and maintenance costs.
Data ownership	Patients own their data and can share it with whom they want.
Complete medical history	Patients' records are scattered throughout different health systems. Blockchain technology ensures the availability of one lifelong EHR.

Unnecessary procedures	Unnecessary procedures include medication, bills handling, and lab test. Blockchain technology has the following capabilities that would reduce or even eliminate issues such as transparency and immutability that would ensure the elimination of performing unnecessary tests and services.

The following Table 9 provides another analysis dimension. Table 9 investigates issues within the current healthcare system vis-à-vis blockchain as a solution on several areas.

Table 9. Current Healthcare Issues and Blockchain Solutions

Area	**Current Issue**	Reference	**Blockchain solution**	Reference
Security	The current practices do not comprehensively address security issues. Patient data is subject to data breaches or at high risk of vulnerability to failure and corruption regularly. Also, Healthcare organizations are responsible for data recovery, a security contingency plan in place, and are subject to regulatory fines in case of the health data getting compromised. They are solely responsible for maintaining the security and integrity of patient records which can be challenging to recover and ensure the integrity of the data if a malicious entity alters the single copy of the record.	[21] [77] [81] [9]	Blockchain provides a well-advanced level of security and encryption capabilities. It provides encryption mechanisms that minimize potential security breaches. Depends on the sensitivity of the data, on-chain and off-chain storage is permitted.	[76] [66] [65] [89] [46] [48] [49] [54] [67] [74] [77] [78] [79] [81] [83] [88]
Interoperability	Patient records are scattered across multiple healthcare facilities, and sometimes it is not accessible when needed. The lack of timeliness of the information and inadequate referral letter content is a significant source of dissatisfaction among medical providers. In many cases, physicians	[128] [11] [129] [142]	Blockchain, by design, helps in overcoming the fragmentation of the scattered health data across different healthcare facilities. It provides a decentralized ledger with the same copy distributed among the network participants that enables interoperability and efficiency. Blockchain	[76] [46] [49] [69] [75] [77] [78] [83]

	struggle to locate the necessary information to make informed patient care decisions during a visit. Another issue is the miscommunication between healthcare providers during care transitions is a critical safety issue and results in serious medical errors.		helps in eliminating the need for data reconciliation across all these parties, which would save massive efficiency and money. It facilitates access control for health information exchange and allows the secure transfer of patient records.	
Cost	The current healthcare systems account for costs that can be avoided. The costs include administrative cost, waste costs, and human error costs. The US healthcare waste in 2009 estimated to be around $700 Billion. Different studies have examined the waste and unnecessary services in healthcare, excess administrative costs, inefficiently delivered services, prices that are too high, fraud, and missed prevention opportunities. Other sources of costly waste include overtreatment, failures of care coordination, failures in the execution of care processes, administrative complexity, pricing failures, and fraud and abuse. Also, medical errors cost the US healthcare system around $17-$29 billion annually. However, full utilization of HIT should result in a cost-saving of around $80 billion.	[119] [4] [5] [122]	Blockchain provides different functionalities that help in avoiding wastes and potentially save money. There are many cost savings that Blockchain offers. Smart contracts allow for the automation of various tasks that traditionally require intensive labor forces. It helps in reducing the administrative cost, eliminating human judgment, errors and their associated costs. It helps in reducing transaction costs as well. Blockchain helps to avoid the frequent need for backups and reduce back-office data input and maintenance costs. Blockchain technology helps to eliminate the need for intermediaries and its associated costs as well as eliminating the need for data reconciliation.	[123] [44] [46] [54] [67] [68] [69] [72] [82] [75] [78] [87] [83] [90]
Data integrity	Data integrity is a crucial part of health information exchange. Data integrity means that data should be correct, free of	[92] [131] [132]	Blockchain ensures data integrity. Distribution of the patient records and the immutability allows for greater integrity of the	[86] [54] [63] [68] [77][78] [79] [81] [83]

	misleading information and errors. The lack of information or incorrect information at the time of patient care has been considered as a major problem in the current healthcare system, leading to medical errors and adverse events. Around 80% of medical errors involve informational or personal miscommunication [131]. Misinformation in medical records, mishandling of patients' requests and messages, inaccessible medical records, and inadequate reminder systems among these issues. CMS found that 52 percent of provider directory locations listed had at least one inaccuracy.		exchanged data. It ensures that no centralized authority exists that can be vulnerable and at the risk of security attacks. The data in the network are agreed upon and immutable. Blockchain enables a higher level of traceability and transparency so that data integrity is ensured and protected against any tampering or misuse.	
Data ownership	In the current healthcare system, healthcare organizations act as custodians or stewards of the patient data leading to inefficiency and delay in the patient care. Patients have less control over their records.	[21]	Blockchain technology offers patients with full ownership over their health records. Patients have ownership of their data and can grant access to whom they wish to share their data with.	[76] [78] [17]
Life-long records	Patient records are scattered across different healthcare facilities. Also, current EHRs are not meant to create a lifetime record of patient history.	[10]	Blockchain technology offers the ability to securely access patient's longitudinal health data across the distributed network. It can create a life-long and longitudinal patient health record.	[76] [90] [80] [140]
Unnecessary procedures	Unnecessary procedures involve issues with medication, bills handling, and lab tests. A survey of 2,106 physicians showed that 20.6% of overall medical care was unnecessary. Difficulty accessing	[119] [14]	Blockchain technology has several capabilities that would reduce or even eliminate various existing issues. Blockchain transparency and immutability ensure the elimination of performing unnecessary tests and	[44] [54] [68] [72]

	medical records results in performing unnecessary procedures. Also, [16].		services. It helps to avoid unnecessary procedures by automating various actions as well as improve access to up-to-date health records in an efficient way. It as well eliminates nonvalue generating processes, human judgment, and errors.	

2.7 Web of Science search

The Web of Science engine (https://webofknowledge.com) was the tool chosen for an overview of literature related to blockchain. The key terms related to this research were "Blockchain", "Blockchain in Healthcare", "Blockchain Adoption", "Blockchain Challenges", "Blockchain for Healthcare Data Management", "Blockchain for EHR", and "Blockchain assessment." The search results reflect research of the last 10 years. Most of the blockchain research has been published in recent years due to recent development of blockchain as an emerging technology. In the last 10 years there has been increased interest in blockchain as a platform in other industries outside of healthcare.

Web of Science engine search results for the keywords "Blockchain" show that more 90% of the research in Web of Science was published within the last three years(see Figure 2). The key search terms "Blockchain Adoption" in Figure 3, "Blockchain Challenges" in Figure 4, and "Blockchain assessment" in Figure 5 show the level of interest in Blockchain increasing within recent years. The key search terms, representing the scope of this research, "Blockchain for Healthcare Data Management" in Figure 6, "Blockchain for EHR" in Figure 7, and "Blockchain in Healthcare" in Figure 8 and Figure 9, and "Blockchain Readiness" in Figure 9 show a limited literature publications related to blockchain technology utilization in relation to the management of the electronic health records and patient's data.

Field: Publication Years	Record Count	% of 2,631	Bar Chart
2019	522	19.840 %	
2018	1,364	51.843 %	
2017	577	21.931 %	
2016	133	5.055 %	
2015	23	0.874 %	
2014	10	0.380 %	
2013	2	0.076 %	

Figure 2. Web of Science search results for the keyword: "Blockchain"

Field: Publication Years	Record Count	% of 136	Bar Chart
2019	33	24.265 %	
2018	64	47.059 %	
2017	23	16.912 %	
2016	12	8.824 %	
2015	1	0.735 %	
2014	3	2.206 %	

Figure 3. Web of Science search results for the keywords: "Blockchain Adoption"

Field: Publication Years	Record Count	% of 550	Bar Chart
2019	141	25.636 %	
2018	287	52.182 %	
2017	107	19.455 %	
2016	14	2.545 %	
2014	1	0.182 %	

Figure 4. Web of Science search results for the keywords: "Blockchain Challenges"

Field: Publication Years	Record Count	% of 50	Bar Chart
2019	11	22.000 %	
2018	29	58.000 %	
2017	9	18.000 %	
2016	1	2.000 %	

Figure 5. Web of Science search results for the keywords: "Blockchain Assessment"

Field: Publication Years	Record Count	% of 33	Bar Chart
2019	13	39.394 %	
2018	14	42.424 %	
2017	4	12.121 %	
2016	2	6.061 %	

Figure 6. Web of Science search results for the keywords: "Blockchain for Healthcare Data Management"

Field: Publication Years	Record Count	% of 12	Bar Chart
2019	4	33.333 %	
2018	6	50.000 %	
2017	2	16.667 %	

Figure 7. Web of Science search results for the keywords: "Blockchain for EHR"

Field: Publication Years	Record Count	% of 117	Bar Chart
2019	34	29.060 %	
2018	59	50.427 %	
2017	19	16.239 %	
2016	5	4.274 %	

Figure 8. Web of Science search results for the keywords: "Blockchain in Healthcare"

Field: Publication Years	Record Count	% of 144	Bar Chart
2019	25	17.361 %	
2018	77	53.472 %	
2017	36	25.000 %	
2016	6	4.167 %	

Figure 9. Web of Science search results for the keywords: "Blockchain in Healthcare"

Select	Field: Publication Years	Record Count	% of 7	Bar Chart
	2019	6	85.714 %	
	2018	1	14.286 %	

Figure 10. Web of Science search results for the keywords: "Blockchain Readiness."

In relation to an organization's readiness for blockchain technology adoption, literature has been investigated. One study presented a Blockchain Readiness Index (BRI) to assess and monitor the level of blockchain maturity [143]. The BRI covers five indicators: Government Regulation, Research, Technology, Industry, and User Engagement. Another study looked at the enterprise readiness of Permissioned Blockchain [144]. This study emphasized the challenges involved in making Permissioned Blockchains deployable. The study highlights the importance for organizations to be aware of practical challenges before deploying them Permission Blockchain real-world applications. The study looked at the readiness from a technical perspective by examining the current technical challenges of the blockchain deployment.

Clohessy et al. studied blockchain technology from technological, organizational, and environmental perspectives [105]. Organizational readiness for blockchain adoption was discussed as a factor under the organization's perspective. The paper provides insights into various adoption considerations.

Ozturan et al. examined the assessment of the Blockchain Technology Readiness Level of the banking industry in Turkey [145]. The study looked at blockchain adoption by researching how domains of: information systems integration, strategical domain, organizational domain, and technical domain; are related to the areas of adoption of blockchain technology in the banking industry. The study concluded that it is difficult to claim any demographic group is better than the other. The Turkish banking industry is at the beginning of blockchain adoption.

There is a lack of literature investigating the organization’s readiness for blockchain technology adoption. Most of existing publications are limited to technical factors.

2.8 Blockchain Adoption Factors

2.8.1 Financial Perspective

The financial perspective captures the financial side of assessing blockchain technology adoption in healthcare organizations. Topics such as financial fisk and uncertainty, and cost-savings fall into this category. The following Table 10 lists financial factors and their definitions.

Table 10. Financial Factors

Factors	Details	References
Financial Perspective		

Budget Availability	This factor measures the ability of the healthcare organization to dedicate and provide sufficient funds for the blockchain project as well as the budget flexibility with the other associated costs such as operational, maintenance, and expansion.	[80] [83] [105] [146] [147] [94]
Financial Risk and Uncertainty	Blockchain technology is immature, and its implementations are believed to be complex and scarce. The number of projects is limited, and the costs associated with it still hard to be fully determined. This factor measures the ability of the healthcare organization to conduct risk assessments and anticipate various financial costs associated with getting blockchain to work, such as expanding the blockchain network, cost of transactions, maintenance, and scalability.	[17] [80] [83] [148] [146] [147]
Cost Saving	Many healthcare organizations are waiting for a proven and clear return on investment measurements to move on in adopting blockchain solutions and join the blockchain network. Healthcare organizations are failing to recognize a substantial return on investment and the lack of coherent use cases of blockchain technology. Healthcare leaders are still uncertain of the blockchain ROI. Cost reduction could come from automation of intense human actions, avoid costly errors, getting rid of unnecessary intermediaries, record duplication reduction, and data collection time and effort. This factor measures the ability of the healthcare organizations to have cost-benefits analysis and determined financial saving goals generated from the implementation of the blockchain by utilizing various measurements.	[54] [68] [69] [72] [78] [75] [76] [105] [147]

2.8.2 Social Perspective

The social perspective includes topics, such as: Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Decentralization. Stakeholders can take the shape of: patients, providers, policymakers, payers, and physicians. This perspective includes the ability of healthcare organizations to attract and acquire skilled workers, and talents. Healthcare organizations should be willing to operate in a decentralized nature. The following Table 11 lists social factors and their definitions.

Table 11. Social Factors

Social Perspective		
Talent & Knowledge Acquisition	Due to the nascency and immaturity of the blockchain technology and the continuous changes and developments in the technology landscape, healthcare organizations are required to have a higher level of talent and knowledge acquisition capabilities. There is a lack of sufficient skills and talents in the market for blockchain development and the blockchain ecosystem is yet to address the problem effectively. The demand for blockchain talent is growing at over 40% per quarter. A survey of more than 100 executives showed that the struggle to acquire talent is most pronounced in areas or sub-areas related to blockchain. Healthcare organizations should be able to keep up with the knowledge and development of the technology as well as attract the necessary talents to implement and operate the blockchain projects. This includes identifying the skillset needed to implement and maintain the blockchain initiative by leveraging external skills and knowledge. This factor measures the healthcare organization's capabilities and performance to identify, access, acquire external knowledge and talents needed for the development of the blockchain solution for both foundational platform programming and blockchain application development whether the solution is developed in-house or outsourced.	[67] [73] [149] [150] [151] [147] [152] [153] [154]
Stakeholder's Awareness & Acceptance	The awareness of the blockchain technology potential to disrupt the healthcare system and solve many of the current healthcare issues should be understood by the different stakeholders and levels of healthcare organizations from the top management down to IT departments. The challenge with blockchain adoption is more of an educational than technical. This issue resulted in the inadequate realization of the relevance of the technology, the ensuing benefits of adopting it and also its feasible use cases. This factor measures the level of stakeholder's engagement, awareness, and acceptance of the blockchain in terms of adequate realization of its relevance, understanding its potential benefits and challenges, and its existence and impact on the organization's health information technology.	[147] [150] [21] [99] [98]
Blockchain Ecosystem	One of the top external roadblocks to blockchain adoption is working with partners/ecosystem members. It is challenging to get the market participants to join a blockchain network. There has to be a tremendous amount of effort to get healthcare organizations to join the network as well as for them to work with partners/ecosystem members. Getting organizations together to advance shared objectives for technology is among the top barriers of adoption. Effort in creating an ecosystem of partners would include defining use cases, setting standards, developing infrastructure and applications, and operating the blockchain network. Building a	[17] [69] [72][83] [146] [147] [97] [155]

	blockchain ecosystem requires considerable efforts to form the blockchain network and convince healthcare providers to join the network. blockchain requires that the industry develop Strategic alliances and partners. Also, forming a blockchain ecosystem requires active collaboration among regulators and prominent technology providers in order to establish more industry-wide standards to encourage adoption. This factor measures the effort of the healthcare organization to work with partners to build an active blockchain ecosystem that includes creating an environment of shared value, defining use cases, developing infrastructure and applications, operating the blockchain network, and solving any additional obstacles.	
Disintermediation & Business Process	Disintermediation means that transactions are conducted in a decentralized peer-to-peer nature without the need for a central authority to validate and process the transactions. Disintermediation entices industry collaboration and derives new business models. It allows for eliminating nonvalue generating processes and intermediaries. It ensures that no centralized authority exists that can be vulnerable and at the risk of security attacks. All the participants have equal power over the shared data. Disintermediation is considered as one of the leading advantages of blockchain adoption. The challenge with disintermediation is getting the market participants to join the blockchain network as joining the network would require the market participants to give up control of their data to the whole market. This factor measures the willingness of the healthcare organizations to adopt new business process by allowing an auto exchange of data through distributed ledger and eliminating nonvalue generating processes or entities.	[17] [146] [72] [54] [69] [67] [21] [97] [155] [43] [46] [48] [53] [71]

2.8.3 Technical Perspective

The technical perspective involves the challenges that are unique to blockchain projects due to the nature of the technology and its characteristics. This perspective covers topics, such as: Infrastructure Availability & Compatibility, Standardization, Security and privacy, and Blockchain Maturity. The following Table 13 lists technical factors and their definitions.

Table 12. Technical Factors

Technical Perspective		
Infrastructure & Platform Integration	Blockchain requires significant changes to the existing system. In order to make the change or switch, companies must strategize the transition. Blockchain technology should be able to integrate seamlessly with other legacy systems. Healthcare organizations have to either procure or develop blockchain-based solutions that interoperate with their present legacy systems or transform their existing systems to be blockchain compatible. The blockchain technology or even any other technology should be able to integrate seamlessly with the existing legacy systems. The healthcare organization should have sufficient and integration able infrastructure in terms of hardware and software to support the implementation. This factor measures the integrability of the blockchain platform into the current infrastructure seamlessly.	[17] [105] [147]
Standardization	EHR systems use different standards, which makes it harder for data exchange. Standardization requires certain considerations in the implementation phase as well as there is a lack of agreed-upon standards among vendors and clients where many blockchain vendors do not offer compatible software. Effective collaboration between the regulators, technology providers, and healthcare organizations is required to establish industry standards and foster blockchain adoption. Healthcare organizations should undertake initiatives to encourage adoption and promote industry standards. Standardization bodies must define appropriate standards. This factor measures the ability of the healthcare organization to be clear on what data, size and format can be sent to the blockchain as well as agree on common terms, business logic and business flow as they share access to the same data and apply the same smart contract-enabled business logic. Also, healthcare organization should have the willingness and flexibility to collaborate to further develop and recognize standard-setting body to progress blockchain related standards as well as work with blockchain vendors to offer compatible software.	[54] [80] [83] [101] [148] [146] [147] [144]
Security and Privacy	Security and privacy are still the foremost concerns in Blockchain-based healthcare and require concrete security solutions. Due to the importance of data security and the strict regulatory rules on the security of patient health records, blockchain adoption is moving very slow. There still many security concerns surrounding blockchain that has to be addressed before to make its wide adoption in the healthcare industry. Various security issues can arise at different stages of the blockchain development such as the vulnerability of the blockchain to a 51% attack to a greater extent in the initial days of formation. This factor measures the ability of the healthcare organization to	[46] [63] [71] [104] [146] [147]

	mitigate privacy risks, how to use blockchain to improve privacy, discover to what extent blockchain provides security, manage new security risks, and identify the areas of deficiency in the privacy and security of using blockchain for the management of the EHR in order to prevent access to healthcare information by unauthorized entities that can harm patient's data.	
Blockchain Maturity & Use Cases	Blockchain technology is an emerging technology, and it is at a very early stage of its maturity. Blockchain maturity means that the technology has been used, tested, and the capabilities have been proven that includes use cases, skills availability, and knowledge. The lack of real-world applications of the blockchain technology in managing and sharing patient records hinder its widespread adoption. Surveys have shown that the immature state of the blockchain is a significant adoption barrier. Various factors such as regulatory concerns, lack of industry standards, mainstream application deficiency all undermine the technology's innovative potential and create the illusion of an immature technology. This factor measures the activities and efforts of the healthcare organizations to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects. The activities that ensure the maturity of the technology understanding include understand the need for blockchain, translate it in technical requirements and develop it while keeping the product owner well informed, a specialized team with business experts, concept designers and development team specialized in blockchain is highly required.	[18] [54] [73] [147]

2.8.4 Organizational Perspective

The organizational perspective covers certain organizational aspects, such as: Management Support, Organizational Readiness, Training & Skills, and Alignment with HIT Strategy. The organizational perspective involves what need to be considered by management to enable successful and sustainable blockchain adoption within healthcare organizations to overcome adoption barriers. The following Table 12 lists organizational factors and their definitions.

Table 13. Organizational Factors

Organizational Perspective		
Management Support	The top management support is an essential and a cornerstone in the successful adoption of blockchain technology. However, there is a lack of clarity of stakeholders who seems to be motivated to implement blockchain as well as the support of various influencing stakeholders. There is a lack of blockchain technology understand and awareness at the organizational level where top management has shown reluctance to adopt the novel technology. The level of acceptance and realization of benefits of the blockchain technology by the top management is required adoption factors. The top management support is an essential and a cornerstone in the successful blockchain technology adoption. This factor evaluates the level of support, engagement, and approval of the top management to the blockchain initiative.	[147] [105] [73] [150] [81]
Training and Skills	There is a lack of enough in-house skills/understanding required to build and maintain the blockchain. Healthcare organizations should clearly define the skillset and training needed to implement and maintain blockchain initiatives. This includes activities related to training and educating internal staff and technical specialists within the healthcare organization for the development of new and related Blockchain skills and competencies. On the other hand, the blockchain service providers try to address the gap of lack of blockchain talents in healthcare organizations through the utilization of existing workforce, cross-training programs, and collaborations between private and public sectors. Blockchain service providers can take the lead in designing and running blockchain training programs at scale. This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help existing technical specialists involved with the blockchain adoption, implementation, and maintenance attain the required level of knowledge or skill related to blockchain solution as well as expedite the learning process. This includes data modeling and normal system availability as well as whether the solution is developed in-house or outsourced.	[105] [67] [73] [149] [150] [152] [71]
HIT Strategy	It is essential to understand the role of adopting blockchain technology in achieving the higher-level strategic objectives of the healthcare organization. It should help improve patient health care, increase patient engagement, enhance efficiency and cost reduction, improve quality of care and outcomes, and enhance care coordination. On the other hand, blockchain adoption requires significant changes to the existing system. In order to make the	[17] [21] [72] [105] [147]

	change or switch, companies must strategize the transition. The blockchain solution should be able to integrate seamlessly with the existing health IT strategy. Also, the blockchain solution would mandate and conceive new business models that would require a framework of new regulations and active collaboration with the authorities. This factor measures the alignment of the blockchain solution with the healthcare organization's IT strategy and objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem.	

2.8.5 Regulations & Legal Perspective

The regulations & legal perspective includes regulatory and legal aspects needed to assess blockchain adoption in healthcare organizations, such as: Regulations Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. The regulations & legal perspective involves interaction with external environment issues and entities. The following Table 14 lists regulations & legal factors and their definitions.

Table 14. Regulations & Legal Factors

Regulations & legal Perspective		
Regulation Compliance	Regulation involves the extent to which the blockchain can comply with the existing security and privacy regulations. The diffusion and acceptance of the blockchain technology for the management of the EHR relies main in the ability of the technology to comply with healthcare regulations and meet with legal rules such as data sharing, privacy, and security regulations as well as being flexible in adapting to new regulations and policies. This factor measures the healthcare organization's effort to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with blockchain technology such as HIPAA, PHI, data sharing, and technological laws in order to satisfy the compliance aspect, preserve data privacy. and adherence to privacy regulations.	[17] [73] [80] [149] [155]
Regulatory Uncertainty & Governance	Blockchain technology is emerging, and immature technology that is in the early stage of its life and the regulations around it is still uncertain. Regulatory bodies should consider deep collaboration with the industry	[73] [83] [84] [140] [148] [146]

	to facilitate adoption. Organizations should work with regulators to define standards to preserve the privacy of users' medical records policies as well as allow projects to proceed within a legal framework and facilitate the growth of blockchain ecosystems within the bounds of the existing regulatory framework. Also, the ability of the healthcare organization to work with partners to set up the rules that govern and administrate the blockchain network in response to the regulatory uncertainty as well as the development of the technology itself. On the other hand, governance is a clear understanding and well-developed rules related to the reading, write, and participation in the blockchain network as well as the rules that administrate the blockchain network. Governance enforces real-world regulations on the blockchain network. This requires healthcare organizations to have the ability and flexibility to address new changes, updates, and unanticipated events related to the technology, the network, and work with key partners toward solutions. Governance facilitates decision making that stakeholders feel represents their interests and preferences as well as work toward the best interest of the network. A clear governance structure should be in place to manage the network involving multiple disparate parties. Also, governance includes rules that address issues related to security standards, appropriate use of transmitted data, data access, and clear rules against information blocking. This factor investigates the clarity and maturity of the consensus mechanism, access control, smart contracts, the rules that administrate the blockchain network, what data to be stored on-chain and off-chain as well as the flexibility to adapt to and address new changes in the regulatory landscape by assessing the legislative changes and take timely actions.	[147] [155] [156] [157] [158] [159] [160] [161]
Incentives Availability	Healthcare organizations should be incentivized to adopt blockchain and join the blockchain network of partners. Incentives to adopters provided by the government could encourage organizations to adopt the technology and participate in the data exchange. Participation could be encouraged through financial incentives by offering programs, similar to the Center for Medicare and Medicaid Services (CMS)'s Meaningful Use program that incentivizes providers to switch to electronic medical records, that could increase adoption and facilitate a nationwide blockchain health exchange. This factor examines the ability of the healthcare organization to work with partners and government officials as possible to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the blockchain network.	[17] [83] [80] [85] [91]

CHAPTER 3: RESEARCH GAPS, GOAL, AND OUTPUT

3.1 Research Gaps

The issues in the current Healthcare IT (HIT) practices mandates the investigation of new approaches to manage and exchange patient records. One approach is the implementation of blockchain technology. Issues, in the current healthcare system, for which blockchain would be a viable solution for, were discussed in section (2.6).

3.1.1 Overview

For this study, a comprehensive literature review has been conducted, to identify and investigate existing literature, related to the assessment of blockchain technology adoption for the management of Electronic Health Records (EHR) systems. The research focused on exploring; methodologies, approaches, theories, or practices that have been used by healthcare providers in the management of patient records, and the recent implementations and frameworks of blockchain in healthcare. The research investigates benefits and challenges of blockchain technology adoption. The research identifies factors impacting blockchain technology adoption for the management of the EHR systems. Blockchain technology is a new concept that emerged in recent years as a platform that facilitates the management and exchanges of patient records.

There is a lack of studies that assess the blockchain technology adoption for the management of Electronic Health Records (EHR) systems. The research investigated, in the literature review, regarding the potential adoption of the blockchain technology for EHR is limited to only identifying blockchain benefits and challenges; and how it provides better management of the EHR systems. Katuwal et al. investigated blockchain literature to examine the blockchain technology applications and implementations in the management of patient records and concluded that “most of the blockchain projects are limited as white-papers, proof of concepts, and products with a limited user base. However, we observed that the quantity, quality, and maturity of the projects are increasing” [17]. Blockchain implementations have been struggling to succeed. Blockchain is an emerging technology. The current models of the blockchain are: immature, can be challenging to scale, poorly understood, and are unproven in mission-critical [18] environments. Blockchain is maturing rapidly, as implementations are moving quickly, beyond the pilot and proof of concept phase [19]. Business challenges of blockchain are often more significant than those posed by technology [20] itself.

Recent reports show that a high number of blockchain projects are either shutting down or scaling back in terms of their goals and timelines [22]. It is estimated that 90% of these projects will not survive to be operational [22]. Forrester tracked 43 blockchain projects, that proposed blockchain as revolutionary, in their respective industries and concluded that none of these examined projects had achieved their full implementation objectives [23]. According to the VP of the Forrester, “In 2018, we expect to see a number of projects stopped that should never have been started in the first place.” [24]. There is a lack of research that addresses and evaluates the factors impacting blockchain technology adoption for the management of the EHR, in a structured and systematic way.

Based on the findings from the literature review, several research gaps have been identified, the research objective was formed, and the research questions were introduced. The following section introduces the research gaps, objectives, and questions.

3.1.2 GAP Analysis

Drawing from the previous literature review about blockchain, the following section introduces the gaps that have been identified:

GAP 1: Lack of Assessment from Multiple Perspective

The multi-criteria decision model has proven capabilities to assist decision-makers in evaluating new technologies. In studying the adoption of the blockchain technology in the management of the EHR, it was found that there is a lack of a holistic assessment of healthcare organization readiness for blockchain technology adoption. Specifically, in the management of Electronic Health Records and its impacting factors, in the existing healthcare system, from multiple perspectives in a qualitative, quantitative, and systematic way. Thus, there is a need to consider multiple critical perspectives that take into consideration various influencing factors into the assessment and then propose a model that can facilitate assessment. The study of the assessment of the blockchain technology adoption, for the management of the Electronic Health Records, from different perspectives; clarifies understanding of the industry picture, and the factors that would influence, and provide successful adoption of blockchain technology for EHR systems.

GAP 2: Lack of a Comprehensive Hierarchical Model: lack of approaches

There is a lack of studies to assess the blockchain technology adoption, for the management of Electronic Health Records (EHR), in a comprehensive way. Most of the research publications focus on the technical aspects, such as: proposing technical frameworks for implementation, illustrating the technical capabilities of blockchain technology, suggesting use cases, and focused on technical criteria for assessment. The current studies on blockchain are focused on inherited characteristics and present the benefits and drawbacks of blockchain technology implementation in the healthcare context. They also presents the potential for blockchain technology to solve issues in the current healthcare system such as interoperability, security and privacy, and efficiency. There is a need for a holistic framework and model through which healthcare organizations can assess blockchain technology adoption, for the management of the EHR, and help them assess efforts toward blockchain adoption.

GAP 3: Highlight internal and external Factors

There is a lack of studies that highlight internal and external factors important in assessment of the healthcare organization's readiness to adopt blockchain technology, for the management of the EHR systems. Current blockchain technology assessment studies present a limited view or only consider a limited number of factors in the assessment. Most of the literature focus on identifying the assessment factors are based on blockchain technology challenges and benefits. Thus, there is a need to identify and define evaluation criteria to be used in developing an assessment model for blockchain adoption.

GAP 4: Lack of expert's judgments & Quantifications

The current literature is based on studying the characteristics of blockchain in solving various issues in current healthcare system practices, without using integrating expert's judgment and quantifying the importance level of factors considered in assessment of blockchain adoption. There are no studies that utilize expert judgment of: government officials, healthcare executives, blockchain experts, and technical specialists, from different healthcare systems, with different experiences regarding the implementation and adoption of the blockchain technology for the management of the EHR systems. Existing literature identifies and suggests adoption factors without assessing relative importance of factors vis-a-vis each other and/or how they interact with each other.

GAP 5: Need to update the literature related to EHR and Blockchain

There is a need to update literature, related to the EHR, based on emergence of new approaches such as blockchain technology and blockchains widespread implementations in different sectors, specifically concerned with healthcare due to its promising benefits. Current studies focus on development and enhancement of provider's EHR, and exchange of patient records through regional HIE organizations, without the inclusion of whole new approaches, such as the distributed system offered by blockchain. The literature is lacking of evidence of a group of healthcare providers having used blockchain to manage and exchange patient records. Blockchain is an emerging technology, and the healthcare system is still exploring its capabilities and how it can be adopted.

3.2 Research Goal

This research aim is to develop a scoring model to evaluate the healthcare organization's readiness to adopt blockchain technology for the management of the EHR systems. The model should help in guiding healthcare organizations in the blockchain adoption process. Also, it would help in finding out the most critical factors impacting the adoption of blockchain technology for the management of the EHR systems. It would help healthcare providers examine the efforts toward the adoption of blockchain technology. The goal of the model is to facilitate the adoption of the blockchain.

3.3 Research Output

- Identification of the perspectives and criteria for assessing the adoption of the blockchain technology for the management of the EHR systems.
- Identification of the relative importance of each perspective and factor to the assessment process.
- Provide a tool for healthcare organizations to assess the adoption of the blockchain technology for EHR in order to overcome challenges with the existing healthcare system.
- Highlight the disagreement level among experts from different fields and backgrounds on the relative importance of the assessment factors.
- Examine the effectiveness and practicality of the model for assessing the adoption of the blockchain technology for the management of the EHR by healthcare organizations.

3.4 Summary

GAPS

- There is a lack of <u>Multi-criteria holistic</u> studies to assess the blockchain technology adoption by healthcare organizations for the management of the EHR system.
- There is a lack of studies to assess the adoption of blockchain technology for the management of the EHR in a <u>comprehensive way</u>.

- There is a lack of studies that highlights the internal and external factors impacting the blockchain adoption as well as in the assessment of the blockchain technology adoption for the management of the EHR systems.
- There is a lack of studies that quantify the expert judgments and present the importance level of the factors and perspectives considered in the assessment of the blockchain adoption for EHR systems.
- There is a need to update the literature related to the EHR based on the emergence of blockchain technology and its promising benefits.

GOALS

The objective of this research is to:

- To develop a framework that can help assess healthcare organizations' readiness for the blockchain technology adoption for the management of the EHR systems.
- Identify the factors impacting the adoption of blockchain technology.
- Assess the importance of perspectives and criteria of the HDM through expert judgment quantification.

RESEARCH OUTPUTS

- Identification of the perspectives and criteria for the adoption of the blockchain technology for the management of the EHR systems.
- Identification of the relative importance of each perspective and criteria to the assessment process.

- Provide a tool for healthcare organizations to assess their readiness for the adoption of the blockchain technology for EHR systems in order to overcome challenges with the existing healthcare system.
- Highlight the disagreement level among experts from different fields and backgrounds on the relative importance of the assessment factors.
- Examine the effectiveness and practicality of the model for assessing the readiness for the adoption of the blockchain technology for the management of the EHR system by healthcare organizations

The following figure 11 shows the depiction of the research gaps, goal, and output.

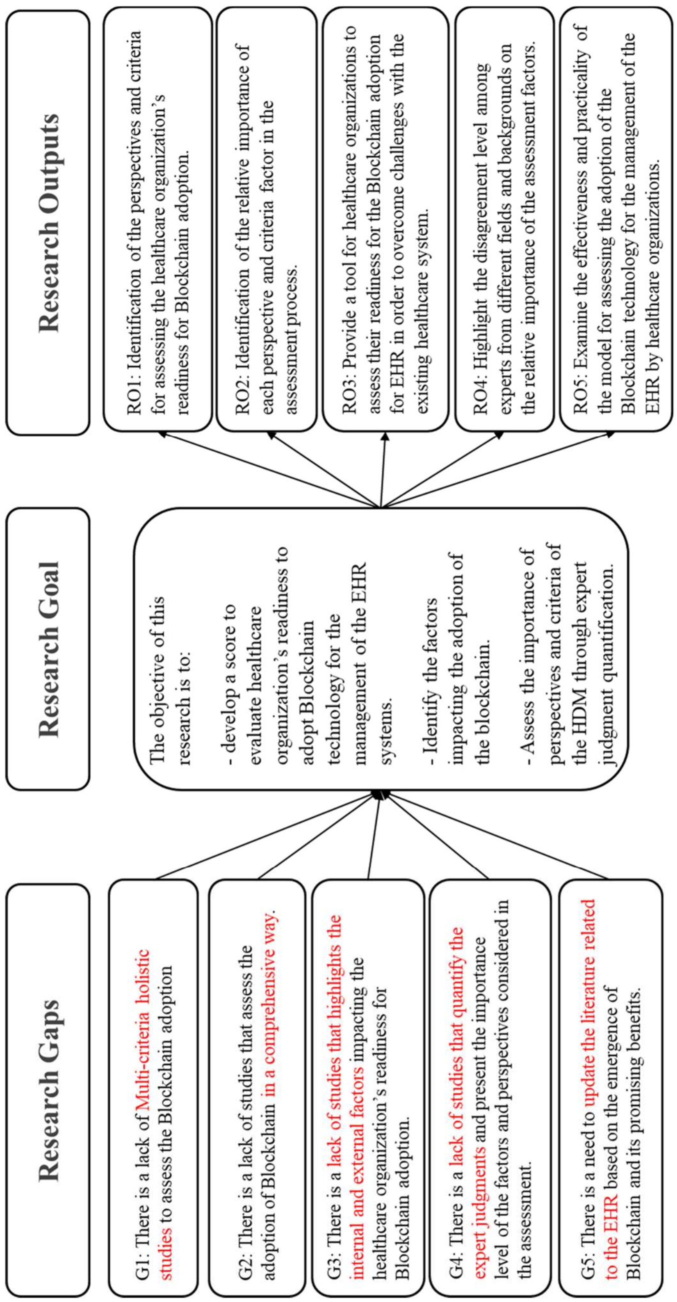

Figure 11. Research Gaps, Goal, and outputs

CHAPTER 4: RESEARCH FRAMEWORK

The research framework followed in this research starts with a literature review, followed by the development of the initial model, then expert panels formation, validation and quantification of the model parameters, desirability curves development, model application and analysis of the results, and finally discuss the results and drew conclusion. The following figure shows the depiction of the research framework phases.

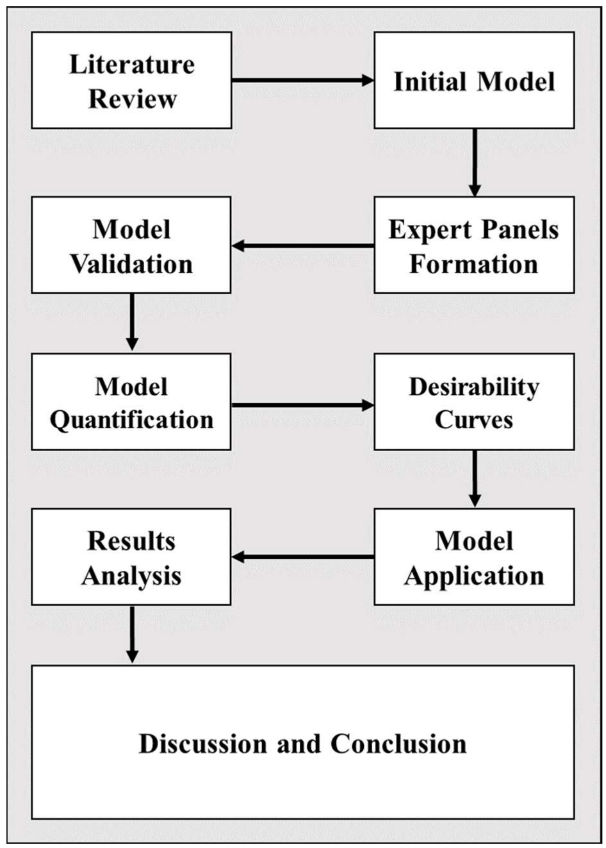

Figure 12. Research Design

4.1 Literature Review

The literature review covers the relevant literature and background information around Health IT, Electronic Health Record systems, current EHR statue, EHR implementations, blockchain technology, blockchain technology in healthcare, blockchain for the management of the EHR systems, blockchain benefits, blockchain adoption challenges and considerations, and blockchain current projects overview. The findings will then be used to develop the initial HDM model. The sources of the knowledge in the literature review are mainly academic publications, including conference papers, journal articles, scholarly books, and reports published by government agencies as well as reports from reputable organizations such as IBM, HIMSS, Gartner, and …etc.

The outcomes of the literature review include:

1.1. Review of the current literature on blockchain technology in healthcare.

1.2. Identify the Research Gaps, Research Objectives, and Research Outcomes.

1.3. Identification of the model elements: Objective, Perspectives, and Factors.

4.2 Research Model Development

Based on the findings of the literature review, the initial HDM model is developed. The developed model is based on extensive analysis of the assessment factors related to the adoption of the blockchain technology for in healthcare. The challenges and considerations surrounding the adoption of the blockchain technology served as the assessment factors. The outcome of this step is to propose an initial HDM model based on the literature review.

4.3 Expert Formation

In this stage, the experts will be identified to provide input to the model, by validating the initial model and then quantifying it. For this research project, subject matter experts were recruited to participate. Section 5.2 provides an extensive discussion of the expert's identification, selection, and panels formation.

4.4 Model Validation and Quantification

In this phase, the expert panel will validate and quantify the model. Feedback from experts will be used to finalize the HDM model. The experts will first validate the model using series of surveys through Qualtrics software. Each model element will be considered validated if two-third (67%) of the expert panel members approve it. If a certain element fails to achieve this threshold, it will be removed from the model. If new element is proposed by three or more experts at any level, it will be added to the model. Then, the experts will quantify the model using the pairwise comparison survey via the ETM HDM software. The expert judgment quantifications will be performed across the levels of the HDM. The outcomes of this step include model validation and model quantification.

In this phase expert panels will be formed for the model validation and quantification as show in the following figures.

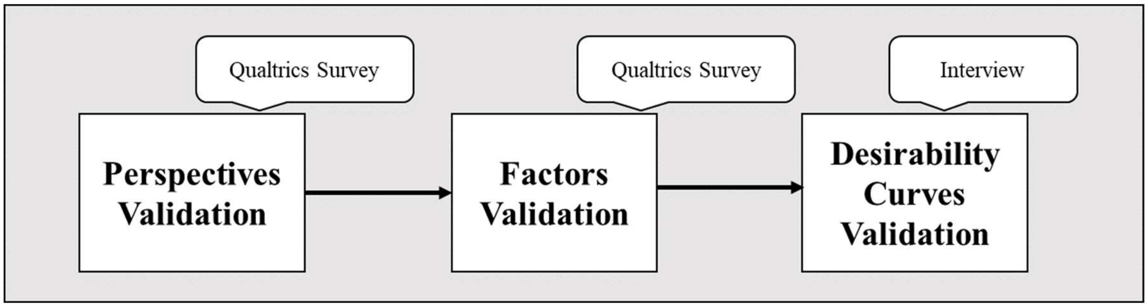

Figure 13. Model Validation Process

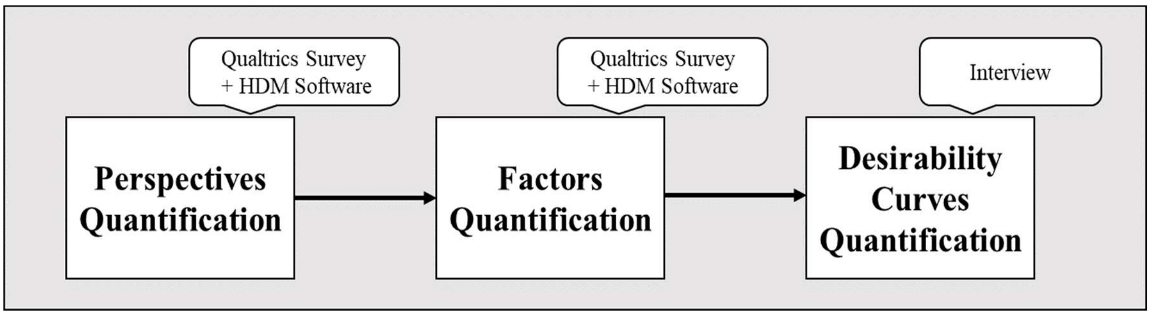

Figure 14. Model Quantification Process

4.5 Model Application and Results Analysis

The results from the pairwise comparisons will first be analyzed to ensure the expert judgments are consistent and the disagreement level between the experts within the acceptable threshold. The ranking of the impacting factors will be introduced in order to understand the most important factors in the adoption of the blockchain technology for the management of the EHR systems. The experts will quantify the desirability curves. The model then will be applied to a case study. The healthcare organization's readiness score will be determined accordingly. The outcomes of this step include analysis of the consistency and disagreement among the experts, the ranking of the factors, and the final healthcare organization's readiness score and analysis.

4.6 Discussion and Conclusion

The last step is to draw a conclusion and propose recommendations based on the result analysis. It should pinpoint the impacting factors and suggest a plan to help facilitate the adoption of the blockchain technology in the management of the EHR and improve the blockchain project's success rate.

CHAPTER 5: RESEARCH METHODOLOGY

An extensive literature review and investigation of the current models and theories used in the assessment of the blockchain technology adoption in healthcare in order to select the most effective and appropriate assessment tool. The Hierarchical Decision Model (HDM) has been identified as an excellent tool in solving such complex and multi-criteria prioritization problem. This section introduces the Hierarchical Decision Model (HDM) and the proposed model.

5.1 HDM Model

5.1.1 Hierarchical Decision Model (HDM) Overview

This research uses the Hierarchical Decision Model (HDM) as the research methodology. The HDM is a multi-criteria decision tool similar to AHP. HDM was introduced by Cleland and Kocaoglu in 1981 [162]. It is used to elicit and evaluate subjective judgments of the experts' panel. The HDM can be used as a network of relationships among decision levels, where expert subjective judgments are provided in a comprehensive evaluation [163] [164]. A hierarchical decision model (HDM) helps the decision-maker by breaking down a complex decision problem into smaller, manageable tasks. Decision-makers have adopted the HDM model in various industries and for a variety of applications [165] [166] [167] [168]. It has been validated and proven to be a reliable and useful tool in addressing the multi-criteria decision problem.

The number of levels in the HDM depends upon the logical sequence and the complexity of the decision involved [169]. The model hierarchy can come in different forms. Typically, the decision criteria hierarchy starts from mission, objectives, goals, strategies, and actions which known as MOGSA [162] [163] [170] [169] [171]. The following Figure 15 depicts the MOGSA structure:

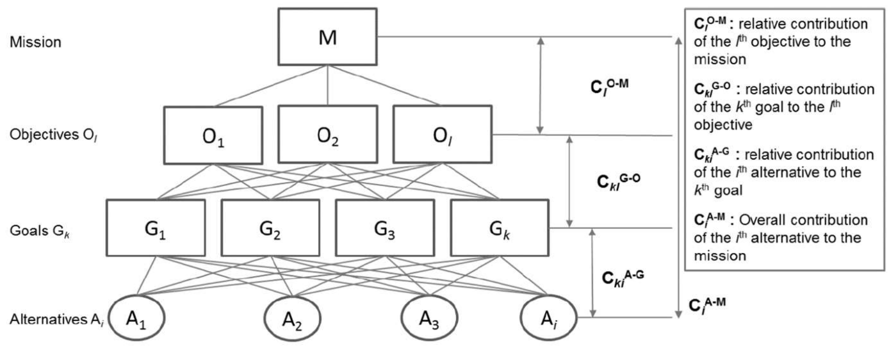

Figure 15. Generalized MOGSA conceptual model design

Based on the constant-sum method, a total of 100 points is divided between any two elements at the same level by the experts. For the level of mission (M), quantifying expert judgment relative to the contribution of the objective level to the mission is given as C_ι^{O-M}. The overall relative contribution of an alternative (A) to the mission (M) is calculated by adding the sum products of all local contribution matrices between M and A. The alternative that is best contributing to the mission can be calculated to find the alternative with the highest contribution to the mission by applying the following equation:

$$C_i^{A-M} = \sum_{\iota=1}^{L} \sum_{k=1}^{K} C_\iota^{O-M} . C_{k\iota}^{G-O} . C_{ik}^{A-G}$$

Where:

$\boldsymbol{Ol}$: Objectives, l= 1, 2, ,.,l

$\boldsymbol{Gk}$: Goals, k=1,2,…,k

$\boldsymbol{Ai}$: Alternatives, i=1,2,…i

C_i^{A-M}: Overall contribution of the i[th] alternative to the mission

C_ι^{O-M}: relative contribution of the L[th] objective to the mission

$C_{k\iota}^{G-O}$: relative contribution of the k[th] goal to the L[th] objective

C_{ik}^{A-G}: relative contribution of the i[th] alternatives to the k[th] goal

For each level, the expert's subjective judgments are collected and translated to relative weights. The alternative with the highest weight sum would be the most optimal for the mission. The model could include more alternatives in the future for evaluation, as there always not be only one perfect solution. Also, the outcomes are not an absolute answer but should be used to inform the decision.

The model as well can be structured in different ways; for instance, HDM hierarchy can start with a goal, perspectives under the goal, and factors within each perspective [169] as depicted in Figure 16.

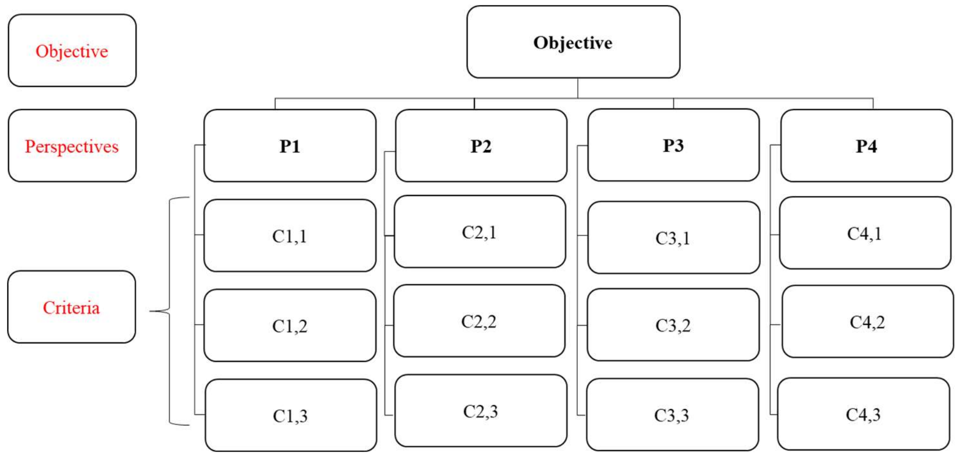

Figure 16. Example of an HDM Hierarchy

HDM follows a similar process as AHP, for instance. HDM steps include constructing and breaking down the decision problem into levels, followed by conducting pairwise comparison among all the decision elements, calculating the priorities and weights of the decision factors, and checking the consistency [172] [173] [163]. The level of the decision tree depends on the complexity and logical sequence of the problem. The connected line from the objective to each perspective means that the perspective must be compared pairwise for their relative importance concerning the objective. Likewise, the lines connecting each perspective to criteria express that criteria are compared pairwise to identify their relative importance to the perspective.

In HDM, the subjective judgments expressed in pairwise comparisons are converted to relative weights in ratio scale which is achieved by a series of mathematical operations. The experts or decision-makers evaluate criteria hierarchy and alternatives by conducting pairwise comparisons, with a constant-sum measurement scale (1–99 scale) for comparing each two decision factors. The methodology can be used for quantifying the judgment of a single decision-maker, or multiple decision-makers [169] [174]. The

HDM process is more comfortable for the experts related to the relative and absolute preference [169] [175]. HDM evaluates and assigns numerical values to the perspectives and criteria. Each factor will have a global weight and local weight within its parent criteria or category. Thereby, bringing clarity to the diverse options available, and displaying the importance and utility of each option lucidly.

The HDM outcomes can be a selection of an alternative. Another way is to substitute the alternatives with desirability curves in case we have many alternatives or the HDM will be used more than once. Desirability curves with HDM are used to identify levels/ metrics for each decision factor. Each level/metric related to a factor represents a useful value for decision-makers or how “desirable” or “valuable” a metric is. It provides a better understanding of the dynamics of each decision element. In this case, the experts will be asked to evaluate common levels for each factor (desirability matrix) and give each metric a scaled quantitative value. By doing so, this allows for the normalization of the evaluation results by experts across all the factors [172] [176] [177] [178].

5.1.2 Calculating the Organization’s Readiness Score

With regards to the research in hand, the goal is to calculate the healthcare organization’s readiness to adopt blockchain for the management of the EHR systems. The expert’s subjective judgment is translated into numerical values using pairwise comparisons. The results will then show the relative importance of the factors to the main objective of this research. Then, the global importance of each factor is multiplied by its desirability value and then make the total summation to determine the healthcare readiness score. The following equation is applied in order to calculate the healthcare organization's readiness to adopt blockchain for the management of the EHR systems:

$$Org\ readiness\ Score = \sum_{p=1}^{P} \sum_{c=1}^{C} P_p\ C_c^p\ d(m_{p,cp})$$

Where:

Org readiness Score = The healthcare organization's readiness score for blockchain adoption.

C: Number of criteria

P: Number of perspectives

P_p: The degree (weight) to which perspective p contributes towards the mission (the mission is readiness assessment of healthcare organization for the blockchain adoption).

C_c^p: The relative contribution of criterion c under perspective p toward the mission.

$d(m_{p,cp})$: Desirability value of the performance metric for c^{th} criterion under p^{th} perspective.

5.1.3 Metrics for Desirability Curves

Value/Desirability Curves Concept

The desirability curves are utilized when the model is used more than once or in case there are many alternatives. Desirability curves supplementing HDM were initially introduced by Phan (2013). Experts quantify the model parameters and desirability metrics which will remain constant but different blockchain projects will be tested against these results using their performance level based on assessing their adoption readiness on the desirability metrics scale. In this research desirability curves will be used to identify how desirable or valuable a metric is for a decision maker. For each factor in the model, experts are presented with the units of measurement and its categories. Experts will assign a value between zero and 100 points to each category for each factor and the bases of how desirable the category is. The curves then are drawn after the average of the experts' assessments is calculated. Desirability curves captures the dynamics or granularity of each factor, i.e. The great advantage of using desirability functions is the flexibility they provide to the model. Below is a sample of a desirability curves for one factor where the rest will be discussed in the initial model development section 6.1.

How to develop them

Expert will be invited to discuss, validate, and assign values for each factor in the model and what are typical situations organizations usually fall into for each factor. They will be asked to identify possible statuses an organization might have against each factor, based on their experience, and what score or how desirable could be assigned with that status. A draft was prepared to assist the experts in evaluating the curves.

How will they be used in the case studies

The first step is to evaluate the healthcare organization's current situation and capabilities for each factor in the model. Then, when running the HDM model, each organization can be assigned to a level that best fit it for each criterion. For example, an organization's current situation for each factor affecting the blockchain adoption will be identified by the project manager after investigating the organization's capabilities. Then the project manager will use the value curve of each factor to determine which level in that value curve is representing the organization's identified situation and based on that the organization will be assigned that level's score.

The readiness score for blockchain adoption is calculated by multiplying the weight of each factor with its desirability value as shown below:

Let:

I : Number of alternatives.

C : Number of criteria.

P : Number of perspectives.

E (a_i) = The readiness score of alternative i.

P_p: The degree (weight) to which perspective p contributes towards the mission (readiness assessment).

C_c^p : The relative contribution of criterion c under perspective p towards the mission (readiness assessment).

$d(m_i, cp)$: Desirability value of performance metric of alternative (i) for c^{th} criterion under perspective (p^{th}).

Then

$$E\,(a_i) = \sum_{p=1}^{P} \sum_{c=1}^{C} P_l C_k^l \, d(m_i, cp) \qquad \text{for } i=1, \ldots, I$$

[176], [172], [177], [178], [175]

The following is an example of a desirability curve for the Management Support factor:

Management Support

This factor evaluates the level of support, engagement, and approval by the top management. Below are the categories:

- Opposed
- Indifferent
- Low to reluctance support
- Good to Enthusiastic Support
- Passionate

Table 15. The result of desirability metrics quantification for the management support factor

Management Support					
	Opposed	Indifferent	Low	Good	Passionate
EXP 1	0	29	56	73	100
EXP 4	0	38	54	72	100
EXP 5	0	11	22	89	100
EXP 6	0	31	52	80	100
EXP 7	0	16	50	82	100
EXP 8	0	29	42	67	100
EXP 9	0	10	20	90	100
EXP 10	0	30	49	74	100
Mean	**0**	**24**	**43**	**78**	**100**

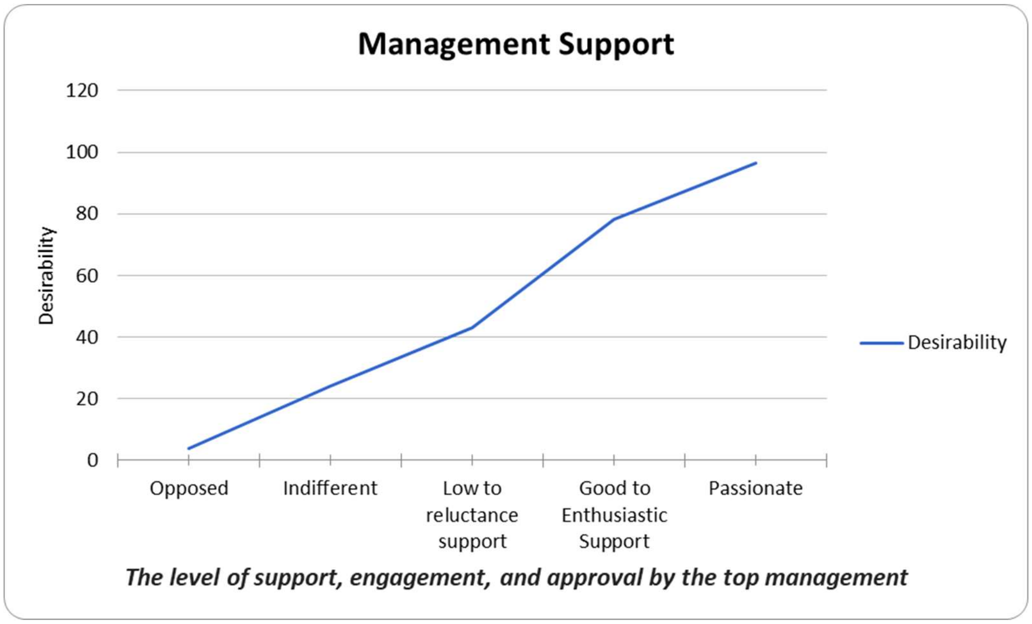

Figure 17. The result of desirability metrics quantification for the management support factor

Further descriptions of the desirability curves definitions, validation, and quantification for each factor is presented in section 6.3.3.

5.1.4 Inconsistency, Disagreement, and Sensitivity Analysis

HDM reliability is validated through inconsistency, disagreement, and sensitivity analysis. Inconsistency in an expert's judgment occurs when there is a disagreement within an expert's evaluation, meaning that an expert could have an inconsistent judgment within his/her comparisons. Disagreements amongst experts can show different quantifications and different perspectives to the same analysis. Sensitivity analysis measure how flexible the model to changes [169] [179] [178] [162] [163] [180]. Inconsistency, disagreement, and sensitivity analysis will be discussed in detail in section 5.2. The discussion will include how to identify, calculate, and treat inconsistency and disagreement in experts' judgments.

Various previous research projects have used a similar approach to the one proposed in this research have discussed and implemented these data analysis measurements, such as:

- Development of a Technology Transfer Score for Evaluating Research Proposals: Case Study of Demand Response Technologies in the Pacific Northwest [177].
- A Scoring Model to Assess Organizations' Technology Transfer Capabilities: The Case of a Power Utility in the Northwest USA [176].
- Development of a Readiness Assessment Model for Evaluating Big Data Projects: Case Study of Smart City in Oregon, USA [172].
- A Measurement System for Science and Engineering Research Center Performance Evaluation [178].

[162], [163], [168], [175], [177], [178], [179], [180], [171], [181]

5.1.5 HDM Benefits

HDM offers many benefits. HDM allows decision makers to break down the decision problem into smaller tasks for analysis and therefore bring a better understanding of the relationship between the decision factors. HDM helps bring clarity to the decision under uncertainty, where there are multiple complexes competing objectives and criteria. It can cover a large number of criteria and sub-criteria, which allows the analyst to cover the topic under investigation from many different angles. HDM is a robust method that can capture the subjective judgment of experts and convert qualitative inputs into quantitative and numeric values. HDM incorporates inputs from diverse experts to create a meaningful and informed decision. The results of the experts' judgment inputs can be tested for inconsistency and disagreement, allowing for more reliable results. It provides more input flexibility and robust method for consistency analysis. The results of the HDM are not just solid numbers or ranking, but rather allow the decision-maker to dive deep into the results and identify other trends or priorities within the same criteria.

5.1.6 HDM limitation

After reviewing the HDM methodology and exploring its benefits, HDM is like any other tool that has strengths and limitations. This section goes through the limitations of the HDM [182], [183], [184], [185], [178], [177], [168], [186], [187], [176], [172].

- HDM is a MCDM tool that has been used to solve similar problems that other MCDM tools are used for and subject to similar limitations. Trying to solve the same particular problem using different MCDM tools may result in different outcomes. This is a result of incorporating different backgrounds, experiences, and experiences in the decision-making process and analysis. Moreover, decision-makers may gain different outcomes, even when utilizing the same tool to solve the same problem. Decision-makers should be aware of such an issue.
- HDM is a great tool to translate qualitative judgment into quantitative information. However, HDM relies heavily on the expert's judgments, which can present some challenges.

- ❖ Finding the right and qualified experts with the needed knowledge to solve the problem in hand is one of the HDM challenges. Experts should have the knowledge as well as the willingness to participate in the decision process. The method's effectiveness decreases when proper and good experts are not involved. A discussion will be presented on the critical issues in forming expert panels in section 5.2.
- ❖ Experts come from different backgrounds and experiences. Experts are humans and their judgments may get affected by biases or other judgments. HDM quantifies the experts' qualitative judgments in order to create a readiness score in this research. In many cases, it is hard to reach a significant level of objective judgment. This issue can be minimized by conducting proper procedures in the selection of the expert panels.
- ❖ Decision-makers should be familiar with MCDM, specifically HDM, process and structure in order to utilize the tool to solve the problem. HDM looks into the complex problems from multi perspectives and breaks down the decision problem into smaller manageable tasks considering various impacting factors. It requires an understanding of the type of data to be collected for analysis.
- ❖ The problem to be solves may require a large number of factors to be considered and evaluated by the expert panels where some analysis issues may arise, such as inconsistency and disagreement within the expert's judgment as well as among the experts themselves. However, such issues are common on HDM and MCDM tools and can be dealt with and treated to produce credible and useful results. Following proper procedures in selecting and forming expert panels as well as a clear

presentation of the research objective can minimize inconsistencies and disagreement issues. Section 5.2 will discuss the inconsistencies and disagreement issues and how they are calculated, minimized, and treated.

- The HDM is capable of breaking down a complex problem into small problems. The number of factors within each level determines the number of pairwise comparisons an expert is required to complete. The more pairwise comparison experts need to complete, the accuracy of result may go down. Experts tend to feel bored and lose concentration the longer it takes them to do so as well as the problem of inconsistency may arise. If n is the number of factors, then the number of pairwise comparisons is n*(n-1)/2. For example, if the number of factors is 8 in a certain level, then the number of pairwise comparisons, an expert is expected to complete is 28. The HDM model should be developed with that in mind without omitting important factors in the problem in hand by structuring the decision model in a way that captures the important factors using reasonable number of factors in each level.
- The decision-maker may need to consider using desirability curves instead of alternatives since introducing new alternatives may result in a change in the outcomes.
- The research focuses on the adoption of blockchain technology in the healthcare context. The current state of the blockchain shows immature technology as well as the projects. As the technology develops and matures, the weights may change. However, the HDM models may lack flexibility as these conditions change. The results of the research are context and time dependent. The financial, organizational, social,

technical, and regulatory factors may not be the same as it is currently. Sensitivity analysis shows how robust and flexible the model is to such changes. The pairwise comparison may need to be redone if a change is observed in factors with high sensitivity.

5.1.7 Methodology Justification

The study of the blockchain technology application in healthcare is a complex task due to the sensitivity of the healthcare sector to new technologies. Disruptive and transformative technologies make their way into healthcare slowly and gradually after being proven in mission-critical and mature. The healthcare sector is, as well, heavily regulated sector. On the other side, blockchain technology requires special attention due to its inherited characteristics and its maturity level.

The methodology to be used in this research has to be able to fulfill the research objective of assessing the blockchain technology adoption by developing a score that assesses the healthcare organizations' readiness for the blockchain adoption in healthcare and be able to answer the research questions. When investigating the adoption of the blockchain technology in healthcare, several internal and external factors have to be taken into accounts such as the maturity of the technology, the certainty of the regulations, the clarity of the costs associated with getting blockchain technology to operation, the availability of supportive ecosystem, and public acceptance. These factors mandate a multi-perspective analysis of the adoption and break down this complex task into manageable subtasks. Also, decision-makers should pay attention to external and internal factors when assessing their readiness for adoption. Currently, not much data is available, and expert judgments are required to be incorporated into the analysis. A MCDM tool, specifically HDM is an ideal methodology to be used in this research due to its benefits and capabilities. Healthcare organizations need a tool that helps them decide where to focus their efforts and pinpoint the weak areas. It should be able to show the weights and impact of each adoption factor and what is the current state of their effort regarding each element and what is the desirable level need to be achieved. The tool should be easy to be used by decision-makers. Finally, due to the scarcity of quantitative data regarding the impacting factors, experts' judgments should be incorporated and converted into numerical values.

Drawing from the previous discussions on the MCDM tools and HDM above, it can be concluded that HDM is one of the most appropriate methodologies that can generate a model that has all the attributes needed to fulfill the research goal and answer the research questions. HDM is the most appropriate tool for this study, and the following are some points that justify my selection of the methodology:

- HDM allows for the decomposition of a complex decision problem into a hierarchy of smaller sub-problems for analysis. The study of blockchain application in healthcare is a complicated task. HDM allows decision-makers to include a large number of criteria and sub-criteria to ensure the investigation of blockchain technology adoption is covered from many different angles.
- The HDM is like the AHP in the structured approach and incorporating expert judgments via pairwise comparisons. However, HDM provides more input flexibility

and a robust method for consistency analysis. HDM uses a constant sum scale (1-99) where AHP uses eigenvalue 9-point scale, which may appear to be a little confusing to use for pairwise comparison.

- HDM is a flexible decision support tool that can be used to quantify expert judgment. It is an effective tool to translate qualitative judgment into quantitative information that facilitates the decision-making process. HDM is capable of handling both qualitative and quantitative data, though, most of the adoption factors are not measurable. HDM incorporates expert judgments and can address its inherited issues, such as inconsistency in expert judgments and disagreement among experts. The adoption of the blockchain technology in healthcare involves a higher level of complexity and uncertainty. It requires incorporating expert judgments in the decision-making process from experts coming from different backgrounds and experiences and convert their judgments to numerical values. Furthermore, due the newness and novelty of the blockchain technology, the knowledge and expertise for blockchain adoption are scattered among various healthcare parties, government, research institutes, and software companies. HDM avoids issues related to expert judgments such as "loudest voice" or "silent bystanders" or the need for physical meetings.
- HDM can handle different scenarios and can be tested for flexibility and sensitivity to changes in expert judgment that result in different criteria weights.

- Healthcare organizations can keep using the developed HDM model to continuously assess their level of readiness for adoption, ensuring that internal and external factors are considered as well as subject matter expert judgments are incorporated.
- Desirability curves add another level of granularity to the analysis where it can show where the healthcare organization stands right now in terms of their readiness for blockchain adoption for each impacting factor and where it should be at (descriptive in terms of the factor's importance and the current level; and prescriptive in terms of where it needs to be to ensure successful adoption). It allows for clearly identifying the desired outcome for each factor. It basically shows the current level and the desired level. The model should be intuitive and easy to use by decision-makers and allows for reusability on various blockchain related projects and at different stages.
- HDM is an analysis tool that goes beyond only showing numbers or ranking to describe the adoption problem. Still, it offers more analysis by allowing decision-makers to dive into the results based on the problem description.
- HDM has proven its capability in addressing complex multi-dimensional problems and as an effective tool in developing a scoring system. HDM has been used in the following similar studies to develop a scoring system and pinpoint areas where improvements are needed:
    - ➢ Development of a Technology Transfer Score for Evaluating Research Proposals: Case Study of Demand Response Technologies in the Pacific Northwest [177].
    - ➢ A Scoring Model to Assess Organizations' Technology Transfer Capabilities: The Case of a Power Utility in the Northwest USA [176].

- ➢ Development of a Readiness Assessment Model for Evaluating Big Data Projects: Case Study of Smart City in Oregon, USA [172].
- ➢ A Measurement System for Science and Engineering Research Center Performance Evaluation [178].
- ➢ Innovation Measurement: A Decision Framework to Determine Innovativeness of a Company [168].

5.1.8 The Generalizability of the Research Model

The extensive literature review conducted on the adoption of the blockchain technology and its application in the healthcare context as well as the previous independent studies and the review of the adoption models have helped in capturing the most important factors impacting the adoption of the blockchain technology for the management of the EHR systems. The factors identified are grouped in perspectives, namely: Financial, Social, Organizational, Technical, and Regulations & Legal. The intended model should be able to be applied to examine healthcare organizations' readiness to adopt blockchain technology for various blockchain projects as well as being able to apply the model at different organizations. It is essential though to understand that the generalizability of the results derived from the research is context and time dependent meaning that at any time in the future the Financial, Social, Organizational, Technical, and Regulations & Legal factors may not be in the same state as at the time of this study.

The model constructs have to be validated in order to achieve the generalizability goal. The validation of the model constructs ensures that the most important factors have been included in the model and the model best represents the reality. The experts will be asked to verify if the model could be generalized to other than the case study application. Experts in the area of blockchain will validate the model perspectives, factors under each perspective, desirability metrics, and the results of the model quantification. The experts chosen to validate the model should have in-depth knowledge in the blockchain technology, come from different backgrounds, and possesses different experiences. An extensive discussion on the expert's selection and panels formation is provided in section 5.2. Special attention should be given to the validation process to ensure reliable results as well as a generalizable model that can be used by different organizations as well as various industries.

Various validity measures will be utilized to ensure reliable results and generalizable model such as inconsistency in expert judgments, disagreement among expert panel members, and the sensitivity analysis to analyze the impacts of potential changes in the values of the different levels of the HDM and gauge the robustness of the model and the change in rank priorities under foreseeable circumstances. Sensitivity analysis also is conducted with the HDM results to develop an overall strategy to meet the various contingencies. It gives a clear picture of how each level and its components relate to each other. SA suggests using multiple scenarios to test how much the ranking would be altered in a particular setting.

Chapter 8 discusses the generalizability of the developed model and ties with the research results. This research follows previous successful dissertations that have discussed generalizability of their research models and used validation panels to ensure the generalizability [168], [172], [175], [176], [177], [178], [187], [188], [189].

5.1.9 Research Validity

The goal of the research validation is to ensure that the adoption model has captured the most important factors impacting the adoption of the blockchain technology for the management of the EHR systems and is valid to apply. The research will use three validity measures, namely: content validity, construct validity and criterion-related validity in order to achieve valid results. The following table 16 illustrates each validity measures characteristics:

Table 16 The validity measures characteristics

Validity	Description	Method	When
Content validity	Degree to which a measure represents a given domain of interest and will test the how ready the instruments for data collection.	Expert evaluation, and literature review	During the model Development
Construct validity	Degree to which a proposed research approach complies with its underlying theories. Is the model correct and capable of serving as assessment tool?	Expert evaluation	Model development and data collection
Criterion-related validity	Degree of effectiveness of the model in performing well and predicting real life phenomenon. (Review of the results by the experts and examining whether they are accurate and valid).	Expert evaluation	After the analyses

One important validation measure, Construct Validity, that has been undertaken to validate the research model was done as part of a pilot study in the comprehensive exam. Construct Validity refers to the fitness of the research approach to past the underlying theories as well as the ability of the model's structure to deal with the problem at hand.

On other words, it tests the readiness of the instruments to gather data from respondents. In this research, the initial decision model that have been developed through the literature review is tested by several of Ph.D. students in technology management before moving forward. Students were asked to participate and act as experts in piloting the research model. They are asked to validate the model constructs and desirability metrics as well as quantifying both the model and desirability curves. The validation of the model and desirability metrics as well as the quantification of the desirability metrics have been done using the Qualtrics survey while the quantification of the model was done using the HDM software.

Content validity refers to the ability of the model contents to properly represent all relevant aspects pertaining to the research topic. In this case, subject matter experts will be identified and contacted to validate each element of the model. The experts will have the freedom to suggest edits to the model, remove items, add or propose new items or sort and organize items within the model in a different fashion. The experts will be asked to validity the research model and the desirability matrices. In this phase seven panels will be formed including perspectives validation, financial perspective validation, social perspective validation, organizational perspective validation, technical perspective validation, and regulations & legal perspective validation, and desirability metrics definitions. In order to validate the items successfully, at least two/third (67%) of the experts in the validation experts' panel should indicate that the perspective or factor is essential. Higher levels of validity are achieved as more expert panel members agree on the items to be included in the model.

Criterion-related validity takes place in the final stage of the research and after the model is applied and during the results analysis. It refers to the validity of the research outcomes and its ability to accurately describe the situation being studied. It measures the degree of effectiveness of the model in performing well and predicting real life phenomenon. It involves the review of the results by the experts and examining whether they are accurate and valid.

This research follows previous successful dissertations that have discussed the research models validation [177], [168], [178], [188], [189], [175], [176], [187], [172].

5.2 Expert's Judgment

5.2.1 Introduction to Expert's Judgment

In this section, various topics related to expert's judgment is discussed. This section will discuss what it means to be an expert, expert's involvement in this research, expert panels, expert's selection criteria and methods, and critical issues and considerations in forming an expert panel.

The elicitation of experts' judgments is a core component of the HDM process and a common practice in academia. Subject matter experts are need for the validation and quantification of the model parameters. These judgments are collected through pairwise comparisons and then converted into numerical values. The selection of experts and the formation of the expert panels are very critical issues. Various literature and previous dissertations have discussed expert judgments and the critical issues around this topic. In answering this question, essential topics that will be discussed include: what makes a person an expert, what is expert panel, role of expert panels in this research, required knowledge, and criteria of selection, selection methods, and critical issues related to expert's selection and panel's formation.

The characteristics or traits of people that make them experts have been discussed in the previous literature, and different definitions have been proposed. An expert is defined by Weiss and Shanteau as a person who has the relevant knowledge and expertise and whose opinions are respected by peers in their respective fields [190]. Meyer and Booker [191] define an expert as "A person who has a background in the subject matter at the desired level of detail and who is recognized by his or her peers or those conducting the study as being qualified to solve the questions.". Also, the Cambridge dictionary defines an expert as " an individual who has a high level of knowledge or skill in a particular field" [192]. Experts are asked to provide their judgment in various fields and for different purposes, such as validation/reviewing research results or identifying critical issues related to a specific topic. The time it takes a person to reach a point where he/she can be considered as an expert is tremendous. According to Ericsson et al., 2007, "It takes time to become an expert. Even the most gifted performers need a minimum of ten years of intense training before they win international competitions" [193]. Expert's judgment on a specific matter is defined as "data given by an expert in response to a technical problem" [191]. Expert's judgment can be used in multiple ways, such as providing insights about a topic or new issue, forecasting of new trends or future event, and analyzing or interpreting data or research results, etc.

Experts' Involvement in the Research

The experts will have several roles in this research. Experts involvement in this research is summarized as the following [175] [194]:

- Validation of the model parameters and desirability metrics and help identify new criteria.
- Quantification of the model parameters and desirability metrics.
- Validation of the research results.
- Recommending other experts (snowball).
- Help gain access to healthcare organizations for data collection.

Expertise Characteristics

Expertise can be seen as a multidimensional prototype that includes seven main characteristics [195], [196], [197]:

- advanced problem-solving processes;
- a significant amount of knowledge;
- advanced knowledge organization;
- effective use of knowledge;
- creative ability by establishing new knowledge based on the knowledge that one already has;
- automatized actions; and
- practical ability by knowing how to get ahead in one's field.

The nature and different constituents of expert knowledge have been discussed and divided expert's knowledge into three main components [195]:

- Formal knowledge, called as well declarative knowledge that is resulting from education.
- Practical knowledge, often called procedural knowledge. This kind of knowledge is a result of acquired skills or "knowing-how".
- self-regulative knowledge. This kind of knowledge consists of reflective skills that people use to evaluate their own actions.

Stages of Expertise

Experts go through a series of milestones in order for them to be considered as experts. Dreyfus and Dreyfus [198] presented a five-stage model of the acquisition of expertise which are:

Stage 1 - Novice: has no previous experience or knowledge in the subject or situations in which they are expected to perform but is able to recognize the basic rules without the desired skill.

Stage 2 - Advanced Beginner: The person begins to develop an understanding of the relevant context; he/she begins to note different from the situation or domain. The person starts to demonstrate marginally acceptable performance.

Stage 3 - Competence: the person starts to develop more skills, acquire experience and knowledge, and understand the complexity of a subject or situation. The person is able to recognize and follow a great number of elements and procedures. The person is now able to demonstrate the efficiency and has confidence in his/her actions.

Stage 4 – Proficiency: In this stage, the proficient person understands a situation as a whole because they perceive its meaning in terms of long-term goals. Proficiency seems to develop if the experience is assimilated in this embodied, atheoretical way. Responses to several situations become automatic and intuitive rather than reasoned.

Stage 5 - Expertise: The person reached a point where they have a deep understanding of the total situation and pose the ability to make more subtle and refined discriminations. The person now is more flexible and highly proficient. The expert is now able to react faster and has an immediate intuitive response for complex situations.

5.2.2 Critical Issues in expert's selection and panel formation

Expert Panel definition and when needed

An expert panel is a group of experts who are engaged when highly specialized input and opinion is needed for a project [199]. They are gathered from various fields of expertise to debate and discuss various courses of action and make recommendations for the goal of helping make an informed decision. The expert panel members should possess current knowledge and be impartial to the research findings [200]. The literature suggests that the formation of expert panels should: have a balanced panel with experts having varied areas of knowledge and expertise and forming unbiased panel toward the decision or problem under investigation [175]. The selection and formation of expert panels is a critical issue that will be discussed in this section.

Expert Panel Size

Various literature has discussed the optimal number of experts in the expert panel to achieve its goal. Defining the size of the expert panel is a significant challenge [175]. Having a very small expert panel may hurt the reliability of the study, and a large number of experts within each expert panel may result in process complexity and the management of the panel may become difficult. Nevertheless, the number of experts within each expert panel varies depending on the level of expertise needed and the goal of the research. Successful studies have been done using as low as three and five experts [201] and [194]. Victoria suggests that the number of experts in the expert panel should be between 2 and 8 experts [199] while Mitchell [202] believes that the expert panel must have at least 8 to 10 experts. Phan used the Delphi method and recommended having 10 to 15 experts for each expert panel [168]. With that being said, many similar dissertations have suggested and used expert panels of 6-12 experts on each panel. Thus, this research will include 13 panels with 6-12 experts in each to validate and quantifying the research model [177], [178], [176], [187], [172].

Table 17. The expert panels roles and optimal panel size used for this study

Panel	Role	Tool	Panel Size
P1	Validate the perspectives	Qualtrics Survey	≥ 6
P2 F	Validate the criteria with the financial perspective	Qualtrics Survey	≥ 6
P3 S	Validate the criteria with the social perspective	Qualtrics Survey	≥ 6
P4 T	Validate the criteria with the technical perspective	Qualtrics Survey	≥ 6
P5 O	Validate the criteria with the organizational perspective	Qualtrics Survey	≥ 6
P6 L	Validate the criteria with the regulations & legal perspective	Qualtrics Survey	≥ 6

P7	Quantify the perspectives	ETM HDM software	≥ 6
P8 F	Quantify the factors under the financial perspective	ETM HDM software	≥ 6
P9 S	Quantify the factors under the social perspective	ETM HDM software	≥ 6
P10 T	Quantify the factors under the organizational perspective	ETM HDM software	≥ 6
P11 O	Quantify the factors under the technical perspective	ETM HDM software	≥ 6
P12 L	Quantify the factors under the regulations & legal perspective	ETM HDM software	≥ 6
P13	Case Studies	Interview	

How experts are identified and employed in this research

Drawing from the previous works in [175] [177] [172] related to forming expert panels for this research, the following steps are to be followed:

- Clarify the research goal and the purpose of the research, what information to collect, and whether the expert judgments are needed to collect the needed information.
- Identify required expertise: the assessment model requires knowledge in the field of healthcare technology projects, technology adoption, assessment of emerging technologies, blockchain technology in healthcare, and academic scholars in the area.
- Search for potential experts' names, the field of expertise, and related organizations to the research. In essence, this step will use the literature review, social network analysis, government reports, websites of organizations in the field of blockchain and healthcare IT.
- Group the identified experts into required panels based on their expertise and what panel they are needed for: the size of each panel will be determined in this step.
- The last step is to send invitations to participate in this research and ask to nominate additional experts

Criteria of expert's Selection

This research relies heavily on the expert's judgments for the validation and quantification of the model parameters and attributes. Various literature and previous dissertations have highlighted the expert selection criteria. The general selection criteria for experts regarding blockchain adoption projects in healthcare assessment include:

1. Experience and Contribution to the field of study
2. Balanced Perspectives and Biases (Absence of bias)
3. Interest and willingness to participate
4. Absence of conflict among expert panel members to avoid skewed data
5. Panel members diversity in term of background, exposure to the topic, and from different organizations to prevent bias by influence issue
6. Technical credibility and independence
7. Skills working on committees and advisory panels
8. Avoidance of dominance by "loudness" and "silent bystanders"
9. Other considerations: academic degree, participation in field related societies, research and teaching, publications, familiarity with uncertainty concepts, and reputation in the subject/field under consideration.

[175], [201], [172], [203], [187], [204], [189], [205], [206], [191], [207], [208], [209].

Experts' Selection Methods

The step following deciding the selection of expert's criteria is the method in which the researcher can employ to find and recruit the experts. Finding experts in the area of blockchain is a difficult task since blockchain is an emerging technology and the widespread knowledge around it is still scarce. There are several efficient and recommended techniques in which the researcher can utilize to find the needed experts. Tran believes that the most proper method of selecting experts is the use of personal connections as a starting point, then follow it by a snowball sampling method, and social network analysis [201]. The following is a list of tools that can be used to identify experts [201] [210] [172]:

- Use of Personal Connections

This is a common way to create a list of experts and use them as a starting point in which the researcher can find other experts. The researcher identifies his/her personal connections whom he/she believes have the knowledge and expertise to participate in the research. This could be people from their LinkedIn circle of connection or interacted with in a local professional group. It is easy and time-efficient but may not be representative of the field. For this research, personal connection is among the expert selection methods used to identify organizations and potential experts as demonstrated in section 5.2.

- Snowball Sampling

This is a method in which experts recommend and refer their peers or other experts to participate in the research. As the name of the method implies, as more experts are recruited and recommended, the group grows like a snowball until the number of experts needed is reached. This is a common method in the scientific community.

- Use of Social Network Analysis (SNA)

Social network analysis methods can be used to analyze a large database where the researcher network can be considered a social network where one researcher usually collaborate with other researchers, cites others' work in their publications. SNA techniques can be used to analyze these citations to reveal the central points in the network, i.e., those researchers with more citations by others. The central researchers can be considered representative of the field, thus identified as expert panel members. Personal profiling and document profiling are the two common approaches for this method. The search keywords describe the person in personal profiling, and in document profiling keywords are used for document searches. SNA uses scientific research databases such as Compendex, Science Direct, Web of Science, etc. SNA is most comprehensive in identifying the best experts. However, SNA process can be time and effort consuming in generating the databases needed, and the experts identified might not be cooperative due to the lack of personal connections.

- Citation Analysis

This method helps to identify experts by using Citation Databases to determine expertise based on papers published and referenced.

- Technology Organizations' Reports

There are well-known and respected organizations that track technologies and publish reports in their advancement and wide adoption. Blockchain adoption has been a hot topic in the recent years and various reports have been published to examine the technology itself and report the current states of adoption such as Gartner's, IBM, and Deloitte reports as well as Harvard Business Review articles.

Critical issues and considerations of using expert panels

There are various challenges and consideration should be taken into account when using expert's judgments. The following are potential issues and considerations associated with using expert panels that the research may face:

- The research objective and question and the role of the experts in the research should be communicated well. Failing to do so may result in an inaccurate judgment leading to less credible results.
- Finding and recruiting right and knowledgeable experts in the research area are a significant successful challenge. The researcher should seek experts with sufficient knowledge and from different backgrounds to ensure accurate and close reality results. A previous section discussed the criteria of selection and methods of finding experts.
- Another critical issue is related to the availability of the experts and their willingness to participate in the research. The researcher should identify and recruit the best experts to the situation and the panel that is needed for to ensure reliable results. In some cases, it might take long lead-time to book appropriate experts. The researcher should be able to seek and identify experts who might be interested in the research and willing to commit their time.

- The potential of expert's judgments biases and overconfidence in their knowledge. This could be a result of expert's relationship to other organizations or if the expert panel was allowed to discuss responses. Also, experts may still be subject to self-interest and personal biases when expressing their judgments. Research should consider experts with no interest in the research outcome and the decision-making process. Also, the researcher should create a balanced representation of experts from various backgrounds and expertise.
- Expert panel size is an important factor that should be considered. Having a very small expert panel may hurt the reliability of the study, while a large number of experts within each expert panel may result in process complexity and the management of the panel becomes difficult. However, the number of experts within each expert panel varies depending on the level of expertise needed and the goal of the research. Successful studies have been done using as low as three and five experts [201], [194]. The most optimal size of an expert panel is 6-12 experts, as indicated in previous dissertations.
- The potential of having inconsistency in expert's judgments and disagreement among the expert panel members is another issue. This issue could be minimized by selecting the right experts and following the selection of expert's criteria indicated above. The design of the model should consider the number of pairwise comparisons the experts are required to perform. A discussion of inconsistency and disagreement issues will be presented in the following questions.

- The issues of dominance by “loudness” and “silent bystanders”. Some experts may influence the judgments of other experts by dominating the discussion. Other, “silent bystanders”, may not properly express their judgments and participate in the panel discussion. The researcher may avoid these issues by eliciting expert’s judgments anonymously and not letting experts meet for discussion. Using electronic communication tools like email or phone instead of meetings is a great way to avoid “loudness” and “silent bystander’s issues or influencing the expert judgments, as well as these tools, are time efficient.

[211], [212], [213], [174], [191], [214], [177], [175], [201], [194], [189], [178].

5.2.3 Experts’ Inconsistencies

Experts will be needed for the model validation and quantification phases. The quantification phase is done using pairwise comparisons where experts are asked to allocate a total of 100 points between two model elements at a time. This method called “constant-sum method.”. During this phase, the experts may present inconsistencies in their given judgments. Inconsistencies occur when an expert’s judgment comparisons are inconsistent. Inconsistency is a critical aspect of HDM and can influence the reliability of the results. The inconsistency analysis is one of the key data analyses of the HDM. Inconsistencies should be measured, controlled, and treated. Inconsistency and its analysis have been defined and explained in the previous literature and dissertations. Estep described the inconsistency in the expert’s judgments as” disagreement within an individual’s evaluation” [177]. Also, Lavoie [176] stated that “The inconsistency level measures how logical each expert is when performing the pairwise comparisons.”.

According to Abotah, "inconsistency is a measure that explains how reliable and homogeneous the answer of the expert through the whole questionnaire" [175]. Moreover, Abbas defines inconsistency in expert's judgments as "Inconsistency is a slight or gross, deliberate or unintentional error in the elicited pairwise judgment related to the rank order and mutual preference proportionality of alternatives.". There is two types of inconsistencies in expert judgments: ordinal and cardinal inconsistency [163] [215]. Ordinal consistency requires the order of preference of the ranked elements to be maintained. For example, if an expert is asked to compare A, B, and C; if the expert prefers A over B, and B over C, then A must be preferred over C. If the expert prefers C over B, then ordinal consistency is violated. However, Ordinal consistency does not take into consideration the strength of a decision maker's comparison. In the case of the cardinal inconsistency, the preservation of preference proportions is required. For example, if the expert prefers A as twice as much as B, and B three times as much as C, the based on the cardinal consistency, the expert must prefer A six times as much as C. if the expert for example prefer A 5 or 4 times as much as C, then the cardinal consistency is violated. Cardinal inconsistency takes into consideration the decision makers preference of one option over another. The Inconsistency analysis process has been discussed and referenced in various dissertation by Estep, Chan, Phan, Lavoie, Khalifa, and Gibson [177] [194] [168] [176] [187] [178].

> "For n elements, the constant sum calculation results in a vector of relative values r1, r2, …, rn for each of the n! orientations of the elements. For example, if three elements are evaluated, n is 3, and n! is 6. The 6 orientations would be ABC,

ACB, BAC, BCA, CAB, and CBA. If an expert is consistent in providing pairwise comparisons, the relative values are consistent for each orientation. However, if an expert is inconsistent in providing pairwise comparisons, the relative values are inconsistent for each orientation. The inconsistency in this methodology is measured by the variance among the relative values of the elements calculated in the n! orientations."

There are two methods to calculate and control the inconsistency in the expert's judgments that have been used. They will be discussed in the following section:

The first method is using the variance method to calculate the inconsistency level by applying the following formulas adopted from [176] [163] [168] [175] [216]:

Let:

r_{ij} = relative value of the i^{th} element in the j^{th} orientation for an expert

$\bar{r}_i$= mean relative value of the i^{th} element for that expert

We calculate the mean first:

$$\frac{1}{n!}\sum_{j=1}^{n!} r_{ij}$$

Inconsistency in the relative value of the i^{th} element is:

$$\sqrt{\frac{1}{n!}\sum_{j=1}^{n!}(\bar{r}_i - r_{ij})^2}$$

For i = 1,2,3…n

Variance of the expert in providing relative values for the n elements is

$$Inconsistency = \frac{1}{n}\sum_{i=1}^{n}\sqrt{\frac{1}{n!}\sum_{j=1}^{n!}(\bar{r}_i - r_{ij})^2}$$

Kocaoglu recommends that inconsistency threshold of 0.10 as the limiting value for the inconsistency for any value of n meaning that the acceptable inconsistency level should be between 0.00 and 0.10 at [163]. If the inconsistency level for a specific expert exceeds 0.10 then it should be handled. The expert with higher than 0.10 inconsistency level should be contacted and explained the inconsistency measurement and clarify any confusion that may have resulted in the inconsistency. Then, he/she should be asked to repeat the judgments; otherwise, his/her judgments could be deleted from the analysis [178] [176]. Another method to analyze and calculate the inconsistency level is using the Root Sum of the Variance (RSV) method that was introduced by Abbas [215].

The second method of measuring the inconsistency is using the Root Sum of the Variance (RSV) method. This method was introduced by Abbas [215] in 2016. RSV proposes using the root-sum of the variances (RSV) instead of the sum of the standard deviations. The RSV measure is linked to the number of decision variables and alpha (α) level to evaluate the soundness and validity of the judgment. RSV takes into consideration the number of pairwise comparisons experts are making as well. The formula to calculate the inconsistency level using RSV as the following [215]:

$$Inconsistency\ using\ (RSV) = \sqrt{\sum_{i=1}^{n}\sigma_i^2}$$

Where:

HDM inconsistency = Root of the Sum of Variances (RSV)

σ_i^2 = variance of the mean of the i^{th} decision element

$$\sigma_i = \sqrt{\frac{1}{n!}\sum_{j=1}^{n!}(x_{ij} - \bar{x}_{ij})^2}$$

Where:

x_{ij} = normalized relative value of the variable i for the j^{th} orientation in n factorial orientations

$\overline{x_{ij}}$ = mean of the normalized relative value of the variable i for the j^{th} orientation

$$\bar{x}_{ij} = \frac{1}{n!}\sum_{j=1}^{n!} x_{ij}$$

Where:

$\overline{x_{ij}}$ = mean of the normalized relative value of the variable i for the j^{th} orientation

x_{ij} = normalized relative value of the variable i for the j^{th} orientation in n factorial orientations

5.2.4 Experts Disagreement

In addressing the expert's disagreement among expert panel's members, various topics will be discussed below.

Introduction to Expert Disagreement

Disagreement among experts is another data analysis measurement in the HDM tool that impacts the validity and reliability of the research results. HDM relies on the expert's judgments and this research employs different experts to quantify the research parameters. It is expected that experts within each expert panel to have different opinions and judgments. The expert's disagreement is normal and can be treated. Amer and Daim define expert's disagreements as "the extent to which members in an expert panel are in difference to each other in their judgments" [217]. Abotaha [175] states that "The disagreement of experts can be understood as the deviation of their judgments from each other.". Also, Tran indicates that "the agreement among the experts' judgment is represented by a disagreement value of the expert group in a pairwise comparison procedure" [218]. The expert's disagreement threshold is set to be 0.10 to judge if experts within the expert panel have a disagreement on their quantification [219]. The expert's disagreement value of 0 means a perfect agreement while a value of 0.10 or higher means unacceptable disagreement level and need to be treated.

Various reasons can justify disagreement among experts. Experts come from different backgrounds and possess different experiences as well as may have different interests in the research topic. Also, even if they have the same background, they may have different knowledge and different ways of approaching different problems. Morgan states that "different groups of experts display different views about the appropriateness of making subjective probabilistic judgments, and have different levels of willingness to make such judgments" [174]. Moreover, expert judgments are needed in situations where quantitative data is hard to obtain or not available and uncertainty exists in the decision problem in hand [220]. Furthermore, the disagreement may be a result of the experts interpreting the question differently, employing different methodologies, or based on different data sources. However, if experts are shown that they have interpreted the question differently, an agreed-upon definition of the problem and what is needed should be sufficient in allowing the experts to redo the pairwise comparisons [221]. The pairwise comparisons instrument should be designed carefully to eliminate the chances of experts misinterpreting the questions.

Why disagreement occur

There are various sources and reasons of expert's disagreements. Three critical sources for disagreement among experts include incompetence, venality, and ideology [222]. Furthermore, the reliability of expert judgment summarized by Yildiz [222] relies on: quality and expertise of the expert panel members, proper administration of the questionnaire and the feedback, ensure clear and standardized instructions without any ambiguity, clarity of questions, consensus/convergence of opinions, and stability of the results between consecutive rounds [221]. Mumpower and Stewart [220] believe that the differences in expert judgments are due to different problem definitions, different ways of thinking, poor feedback, poor quality of data, different information available, false agreement, and causal texture of the environment. Meyer and Booker claim that experts do not retain the same knowledge in terms of experience, education, and how they differ in processing the information. Also, disagreement may appear when experts are provided with insufficient information or guidelines on the elicitation and the problem in hand [191].

A high level of disagreement among the experts can negatively impact the validity and trustworthiness of the experts' judgments and the research topic/model under evaluation in return. Therefore, one a disagreement among the expert panel members identified, there is a need to take corrective actions to resolve and control the disagreement. Proper communication and availability of data can minimize the disagreement.

Disagreement Calculation

The disagreement level measures how much disagreement exists between the various experts. The disagreement index is calculated for j experts for n decision variables in each panel using the formulas below [177] [168] [172] [189]:

Let *m* be the number of experts and *n* be the number of decision variables.

r_{ik} be mean relative value of the i^{th} decision variable for k^{th} expert.

Group relative value of the i^{th} decision variable for *m* experts is:

$$R_i = \sum_{k}^{m} r_{ik} \cdot \frac{1}{m} \qquad \text{for } i = 1,2,\ldots,n$$

The standard deviation of the relative value of the i^{th} decision variable is:

$$\text{STD}i = \sqrt{\frac{1}{m} \sum_{k=1}^{m} (R_i - r_{ik})^2}$$

Disagreement for *m* experts is calculated as the mean standard deviation of the group *n* relative values of variables.

$$D = \frac{1}{n}\sum_{i=1}^{n} STDi$$

A threshold value of 0.10 is used to detect group disagreements. If a group disagreement value exceeds the threshold value of 0.10, then it is concluded that there is disagreement among experts and has to be treated. The hierarchical clustering method is used to identify experts that conflict with the rest of the group. [177] [168] [172] [189].

The methods of measuring disagreements: ICC and F-test hypothesis testing

Two other statistical methods can measure the disagreement among experts within the expert panels with high disagreement level to analyze the level of disagreements: The interclass correlation coefficient (*ICC*) and F-test with hypotheses testing.

Intraclass Correlation Coefficient (ICC) method

Disagreement can be measured using the Intraclass Correlation Coefficient (ICC) method. This method calculates the degree of disagreement among experts for a relative number of elements. Under this method, ICC represents the degree to which (*k*) experts agree with one another on the relative importance of (*n*) elements.

The ICC is estimated according to the following formula, adapted from [223] [224] [176] [187]:

$$ICC = \frac{MS_R - MS_E}{MS_R + (K-1)MS_E + \frac{K}{N}(MS_C - MS_E)}$$

Where:

MS_R = mean square for rows (i.e., targets)

MS_C= mean square for columns (i.e., judges)

MS_E= mean square error

K = number of observations (e.g., ratings or judges) for each of the N targets

N = number of targets or subjects

The ICC value represents the degree to which (*k*) experts agree with one another on the relative importance of (*n*) elements The ICC value should fall between -1 and 1. When ICC value is 1 that means all experts assign the same mean values to the subjects, which conclude an absolute agreement. While a value between zero and -1 is considered as zero and means substantial to total disagreement among the experts. Also, any value between zero and positive one indicates a degree of agreement among the experts. A value of 0.7 or greater means a strong agreement among the experts. [223], [224], [176], [187].

F-test with Hypotheses Testing method

Another method to measure the disagreement is using the statistical F-test. F-test is used to compare the ratio of two variances. It tests a null hypothesis $H_0: ICC = 0$, meaning that there is no correlation between the values, and thus there is an absolute disagreement between the experts. If the null hypothesis is rejected, the $H_1: not\ H_0$ is confirmed, meaning there is not a statistically significant disagreement between experts. The HDM software offers all F calculations. However, The F ratio is calculated by the following formula:

$$F = \frac{MS_R}{MS_E}$$

The resulting ratio is then compared with the F-critical value – with degrees of freedom $df_1 = df_R$ and $df_2 = df_E$ at a specific level of confidence (usually 95% and above). If the calculated ratio is greater than the F-critical value, the null hypothesis can be rejected (at that specific level of confidence), and no significant disagreement between experts would be present.

ICC and F-test are powerful statistical methods to investigate disagreement between experts within the expert panels. The HDM tool used in this research includes F-Test in the results, which reveals the disagreement among experts. ICC only gives a guideline to interpreting the degree of agreement/disagreement among experts, while F-test investigates whether there is statistically significant disagreement among the experts. These two methods determine whether there is a disagreement between experts, and it is important to be able to treat and resolve the disagreement. [187] [177] [225] [224] [176] [221] [168].

How is Disagreement treated? HAC method!

Disagreement among experts within expert panels should be treated. Once a disagreement is found, the statistical process of Hierarchical agglomerative clustering

(HAC) can be used to identify the experts who are in disagreement or agreement. Hierarchical agglomerative clustering (HAC) has been used in previous dissertations to complement the disagreement measurement and interpretation [178] [189] [204]. The objective of the HAC is for clustering to discover natural grouping. HAC is used to identify experts that conflict with the rest of the expert panel and identify clusters and new regrouping of experts. The HAC method uses a bottom-up algorithm that starts with a single expert data point then successively merges pairs of clusters until all points are used. This technique iteratively groups experts according to their similarity in judgment and opinion in clusters (or sub-groups), until each cluster's disagreement levels are within acceptable limits, utilizing dendrograms to visually demonstrate the clusters within each expert group. Once the experts in disagreement have been identified the researcher should contact them to better understand the cause of disagreement.

What should be done about it?

In order to understand and treat the expert's disagreements, the following points should be taken into consideration and actions:

When the disagreement level is above the acceptable threshold level of 0.10, another round of judgments, using the Delphi process, could be conducted in order to reach a consensus or quasi-consensus situation.

Moreover, when the majority of the experts within the expert panel agree, but there is one or a few outliers bringing the disagreement level up, a follow-up with those experts should be conducted in order to check if the objective of the research was delivered well and what they are being asked to do is clear, then the removal of those outliers from the expert panel could also be considered.

If the disagreement is very high, then the first step is to determine whether the disagreement is stemmed from an issue in the elicitation or from the natural differences between the experts. If the issue is coming from the elicitation process, the researcher should contact the experts and clarify the objective of the research and what they are asked to do. But if the issue is stemmed from the natural differences between the experts, then the HAC method should be used to identify the experts causing the disagreement level to go up and contact them to clarify any issues. Also, the Delphi method could be used to allow experts to feed their answers iteratively with repeated rounds until a consensus is reached.

Lastly, the F-test approach can be used to decide if a disagreement beyond 0.1 is acceptable or not. F-test is a statistical test that is mostly used to decide if a statistical model as a whole is significant and is the best fit for a set of data using the least squares. The F-test is compared to F-critical as discussed above in the F-test with the hypothesis testing section. [177] [176] [168] [178] [224] [204] [189].

5.2.5 Sensitivity Analysis

Technology evolves, and the decisions around them change. Blockchain technology is an emerging technology, and its maturity is growing and the regulations around it continue to mature as well. This research is conducted at one point in time and it is crucial to provide insights into how the outcomes of this research would be impacted by changing priorities. Thus, there is a need to develop a model that can adapt to such changes. Sensitivity analysis is used to analyze the impacts of potential changes in the values at any level of the HDM. Also, It is used to gauge the robustness of the model and the change in rank priorities under foreseeable circumstances [215]. The sensitivity analysis (SA) method proposed in this research was developed by Chen and Kocaoglu [180] [226]. The SA algorithms were developed based on a series of mathematical deductions. Chen and Kocaoglu [258] employed two approaches to sensitivity analysis: the operating point sensitivity coefficient (OPSC) and the total sensitivity coefficient (TSC). The SA algorithm uses an additive function to derive the overall contribution vector. HDM SA algorithm identifies the allowable range/region of perturbations, contribution tolerance, operating point sensitivity coefficient, and total sensitivity coefficient. The sensitivity analysis of the HDM is used to determine the allowance of perturbation induced on each element without any impact on the original ranking based on the readiness score meaning that the rankings from the readiness score will not change as long as the values of the perturbations remain within the allowable range of values. Sensitivity analysis is conducted with the HDM results to develop an overall strategy to meet the various contingencies. It gives a clear picture of how each level and its components relate to each other. SA suggests using multiple scenarios to test how much the ranking would be altered in a particular setting. Furthermore, different scenarios can be used to test the sensitivity of the model to changes in order to calculate how much perturbation in its priorities a model would endure before producing different results. This is done when the decision-maker believes that the importance of a specific perspective level changes. Each scenario changes the relevance of perspectives by boosting one perspective a time. For example, we boost the Financial perspective to be 0.96, while the rest of the perspective's values set to be 0.01 for each and repeat the process for the other perspectives. This method has been used widely in several previous dissertations [177] [176] [175] [172]. Chen and Kocaoglu state that the original ranking of the model (original output) will not be changed if:

$$\lambda \geq P_i^C . \lambda^C$$

for the perturbation P_{l*}^C where

$$-C_{l*}^C \leq P_{l*}^C \leq 1 - C_{l*}^C$$

where

$$\lambda = C_r^A - C_{r+n}^A$$

and

$$\lambda^C = C_{r+n,l*}^{A-C} - C_{rl*}^A - \sum_{l=1,l\neq l*}^{L} C_{r+n,l*}^{A-C} \cdot \frac{C_l^C}{\sum_{l=1,l\neq l*}^{L} C_l^O} + \sum_{l=1,l\neq l*}^{L} \frac{C_{rl}^{A-O}}{\sum_{l=1,l\neq l*}^{L} C_l^O}$$

The allowance range of perturbations C_i^C to maintain the original ranking is given by: $[\delta_{i-}^C, \delta C_{i+}^O]$and the sensitivity coefficient is given by:

$$1/|\delta_{i+}^C, \delta_{i-}^C|$$

[215] [180] [226] [175] [176] [177] [187] [189] [210]

5.2.6 Potential Organizations and Experts

Here are considerations on how the potential organizations and experts have been selected and identified:

- The expert's selection has taken into account all the steps required to identify and select experts as discussed in the critical issues in expert's section and panel formation section earlier in this chapter. The expert's list is believed to have experts with proven expertise and in-depth knowledge in blockchain technology or the application of the blockchain in healthcare. They come from different backgrounds and work for different companies at different industries with more focus on healthcare. They are active in the blockchain community.

- The selected experts belong to either private or public organizations and from academia or industry.
- Academia includes universities, research centers, and universities' technology labs. Some universities have already started offering degrees or certificates in blockchain. Portland State University offers blockchain Certificate accredited by AACSB.
- Industry organizations include big companies that are either investing in blockchain or software companies that started providing blockchain services such as Microsoft and IBM. Also, currently, many startups and ventures have started around providing blockchain consultancy services, and blockchain is considered as their core business.
- Healthcare sector: Healthcare organizations that started adopting blockchain, building use cases, and participating in blockchain ecosystems or alliances. For example, blockchain alliances such as Synaptic Health Alliance which include hospitals, insurance companies, labs, and pharmaceutical company. Synaptic partners are Aetna, Cognizant, Humana, MultiPlan, Optum, Quest Diagnostics, and UnitedHealthcare

- Blockchain associations that work in fostering and boosting the awareness and adoption of blockchain. This includes nonprofit organizations, local blockchain communities, and government initiatives to examine and test the technology.
- Selection methods have considered includes personal connection, snowball, SNA, and citation analysis.

5.3 Review of MCDM Methodologies

5.3.1 Introduction to MCDM

Current systems and decision-making problems mandate using approaches that handle multiple criteria. Multi-criteria decision analysis (MCDA) tools provide a reliable methodology to assess different alternatives using multiple criteria. Devlin and Sussex [227]defined MCDA as "a set of methods and approaches to aid decision-making, where decisions are based on more than one criterion, which makes explicit the impact on the decision of all the criteria applied and the relative importance attached to them". MCDM tools can handle quantitative and qualitative criteria and analyze conflict in the criteria and decision making.

MCDM methods provide reliable and flexible tools that can assess a wide range of variables in different ways and offer useful insight. They allow a more comprehensive understanding of the decision-making problem, decision-makers may not be familiar with the problem, compromising and coherent decisions are easier to be accomplished, and the problem is analyzed in a realistic framework [228]. MCDM allows for incorporating qualitative inputs where quantitative data are not available, and uncertainty exists. The MCDM approaches provide a logical, well-structured decision-making process based on the quantitative analysis through scoring, ranking, and weighting of qualitative and judgmental data [194].

There are many MCDM tools that can handle various decision-making problems. However, none of them is capable of solving all kinds of decision-making problems or situations. The utilization of the MCDM tools depends on the problem in hand. Using different MCDM approaches for the same problem may produce different outcomes. No single tool fits all problems. Different tools fit different situations.

MCDM tools generally fall into two categories: multi-objective decision making (MODM) and multi-attribute decision making (MADM) [229] [230]. MODM involves multiple competing objectives that should be optimized under several realistic constraints. MADM tools evaluate a set of alternatives against a set of criteria or attributes. When solving complex problems, MADM tools are often used, and it's the most popular MCDM methods.

Various authors explained the process in which MCDM tool are constructed. Merkhofer [231] states that the application of decision analysis starts with decomposing the decision problem into its basic elements (choices, information, and preferences), followed by quantifying each element, and finally applying axioms of normative decision theory to identify a logically consistent alternative. Similarly, Pohekar and Ramachandran [230] suggests that MCDM tools follow basic steps:

- Structure the decision process, which involves alternative selection and criteria selection.

- Performance evaluation: demonstrate the tradeoffs between criteria and determine their weights.
- Decide decision parameter: which involves applying value judgments regarding acceptable tradeoffs and evaluation.
- Evaluation of results and decision making.

Thokala and Duenas [232] analyzed the possible application of MCDA methods in health technology assessment and discussed their relative advantages and disadvantages. They classified MCDA approaches into three categories: value measurement models such as weight sum method and AHP; Outranking methods such as ELECTRE and PROMETHEE-GAIA; and goal programming methods such as goal programming, heuristics, and meta- heuristics. The author's review of the literature suggests that value measurement models are the most recommended approaches for health technology assessment (HTA) by many authors, while outranking methods are not widely used in health care. The analysis of the difference, advantages, and disadvantages of these methods shows that outranking and goal programming methods appeared to be easier to follow, while significant computational time is needed for goal programming. Moreover, results from value measurement models offer easy visual presentation while results from outranking and goal programming methods are challenging to follow. Finally, uncertainty is easier to incorporate in value measurement models than in outranking or goal programming methods. The authors emphasize the significance of understanding and choosing the right MCDM approach for the right situation in the health technology assessment in order to ensure the success of the appraisal process.

Furthermore, Thokala and Duenas [232] suggests that MCDA methods consists of the following steps:

- selection of the alternatives to be assessed,
- identification of the criteria (or attributes) against which the alternatives are evaluated,
- scores that reflect the value of an alternative's expected performance on the criteria,
- criteria weights that measure the relative importance of each criterion against other criteria.

HDM is a well-known MCDM approach that fits the goal of this research. HDM is selected to assess the adoption of blockchain technology for the management of the EHR systems. The flexibility of the HDM as a MCDM tool method can handle both qualitative and quantitative data allowing for a holistic and comprehensive approach.

5.3.2 Selected MCDM tools

A summary of the most well-known MCDM methods is presented below, followed by table 19 showing the strengths and weakness of each approach:

TOPSIS

TOPSIS is MCDM tool that was developed by Hwang and Yoon in 1981. TOPSIS stands for Technique for order preference by similarity to ideal solution. The tool assumes that the ideal alternative has the best level for all criteria, whereas the negative ideal is the one with all the worst criteria values. The optimal alternative should have the shortest geometric distance from the positive ideal solution and the longest distance from the negative solution. The optimal solution maximizes the benefit criteria and minimizes the cost criteria. On the other hand, the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. TOPSIS combines quantitative and qualitative attributes to compare all alternatives against them.

In the context of health technology assessment, Mobinizadeh et al. [233] used TOPSIS to assess three technologies that were available for projects call of the Iranian health technology assessment department in order to determine the applicability of the model for a practical purpose. The model included nine criteria and three technologies. The results show that the proposed model is applicable for the assessment of health technologies by the Iranian ministry of health and medical education and can be used for the determination of research priorities in health technology assessment. [233], [234], [235], [236], [237].

PROMETHEE

The preference ranking organization method for enrichment evaluation (PROMETHEE) tool is one of the outranking MCDA methods that was developed during the eighties by J.P. Brans [238]. The technique uses the outranking principle to rank the alternatives by performing pairwise comparisons of the alternatives under a set of criteria. In the PROMETHEE tool, six options are allowing the user to express meaningful differences by minimum gaps between observations. developed versions such as PROMETHEE I & II became available in subsequent years.

PROMETHEE initial version was developed to show only the best alternative based on the positive and negative flows, A later version aims at identifying the rank of all options, and they are based on multi-criteria net flow with consideration of indifference and preference thresholds. PROMETHEE incorporates generalized criterion functions in order to consider the uncertainty in the criteria performance values. However, the sensitivity analysis method is used because the generalized criterion functions do not address the subjectivity and uncertainty in the criteria weights. The implementation of PROMETHEE requires two pieces of information: the identification of the relative importance of the criteria considered and comparing the contribution of the alternatives with respect to every criterion using expert judgment.

PROMETHEE follows the following steps suggested by Hyde et al., [239]:

1. identifying decision makers, actors, and stakeholders,
2. selecting the assessment criteria,
3. formulating alternatives,
4. weighting the criteria,
5. assessment of the performance of alternatives under the selected the criteria,
6. selecting a generalized criterion function and associated indifference and preference values for each criterion,
7. applying PROMETHEE,
8. performing sensitivity analysis,
9. making the final decision.

Decision-maker has favored PROMETHEE methods due to their simplicity and ease easy to understand. PROMETHEE incorporates quantitative and qualitative data allowing them to be used for a wide range of decision situations. It is an ideal tool to be used to assess a large number of alternatives. [238], [240], [241], [239], [232], [242].

AHP

Analytic Hierarchy Process (AHP) was introduced by Saaty [243]. AHP is one of the most popular and widely used MCDM tools. AHP assumes that any decision problem is constructed as a hierarchy where the decision is broken down from the top to bottom with the objective in the top, the assessment criteria in the middle level, and the alternatives in the bottom level. The best alternative is chosen by conducting pairwise comparisons of the alternatives against each other with respect to the criteria. The pairwise comparison uses eigenvalues and eigenvectors scale of 1-9 for the quantification of the expert judgments. AHP uses the expert's judgment to quantify the model and rank the alternatives with the highest-ranking being the best option. The inputs of experts and decision-makers are presented as pairwise comparisons, and the best alternative can be selected according to the highest rank among alternatives.

In the AHP, the decision is decomposed into the following steps [244] Saaty, 2008:

- Define the problem and determine the kind of knowledge sought.
- Structure the decision hierarchy from top to down.
- Construct a set of pairwise comparison matrices.
- Calculate the relative importance of the criteria and prioritize the alternatives.

In AHP method, the decision problem is easy to construct. It simplifies complex decision problems and uses expert judgments to present credible results. It uses quantitative and qualitative data. AHP is flexible, intuitive, and checks inconsistencies making it viable for diverse applications. However, the pairwise comparisons would be a tedious process if a large number of factors are considered in the model. Inconsistency requires special treatment if above the 10% threshold.

ANP

Analytic Network Process (ANP) is a later and general form of the AHP that was developed by Saaty [245]. ANP is another MCDM tool that deals with a decision problem as a network of complex relationships between criteria and alternatives where all the elements can be connected. The ANP is an important tool for articulating the understanding of a decision problem, especially in very complex situations. AHP is easy to use and apply but cannot handle the complexity of many situations. ANP structure the problem as a network while AHP as a hierarchy. ANP uses experts' judgments through pairwise comparisons for the ranking and selection of the best alternative. Criteria are independent from each other in the AHP where the hierarchy flows in one direction, whereas in the ANP dependency and bidirectional flow are allowed. The main advantages of ANP is the capability to address very complex problems and provide a deeper understating of certain problems and their related factors. Decision-makers may find it very challenging to understand the ANP process. ANP may require specific and advanced software to calculate the results and incorporate feedback. [245], [246], [247], [248], [249].

HDM

The Hierarchical Decision Model (HDM) is a multi-criteria decision tool similar to AHP. HDM was introduced by Cleland and Kocaoglu in 1981 [162]. This research uses the Hierarchical Decision Model (HDM) as the research methodology. HDM is used to elicit and evaluate the subjective judgments of the expert's panel. The HDM can be used as a network of relationships among decision levels, where expert's subjective judgments are provided in a comprehensive evaluation [163] [164]. A hierarchical decision model (HDM) helps the decision-maker by breaking down a complex decision problem into smaller and manageable tasks. HDM is used to quantify expert qualitative judgments and convert them to numerical values using a pairwise comparison method with a constant-sum measurement scale (1–99 scale) for comparing each two decision factors. Decision-makers have adopted the HDM model in various industries and for a variety of applications [165] [166] [167] [168] [188]. HDM has been validated and proven to be a reliable and useful tool in addressing the multi-criteria decision problems. AHP uses the eigenvector approach (1-9 scale), while HDM uses the constant sum method (1-99 scale), which makes HDM easier to use. One advantage of the HDM is the ability to screen and select a large number of alternatives and compare them against each other under the presence of a large number of criteria. It allows decision-makers to cover the topic under investigation from different angles. An extensive literature and discussion have been and will be included in answering other questions.

ELECTRE

ELECTRE is outranking MCDM method that was introduced by Bernard Roy in 1965 [250], [251]. ELECTRE family includes ELECTRE I, II, III, IV, IS and TRI that have been developed over the years. The acronym ELECTRE stands for 'ELimination Et Choix Traduisant la REalite'. ELECTRE handles quantitative and qualitative data and allows choosing the best action from a given set of actions. The chosen alternative is the one favored the most over a set of decision attributes and fulfill the minimum level of performance level set for each decision attribute. The analysis process focusses on the dominance relationship between alternatives. The tool uses pairwise comparison between alternatives. ELECTRE methods can handle uncertainty well in decision environments as well as its ability to maintain changes in the number of decision criteria and relative weights of the criteria. A major difficulty of using ELECTRE is that the performances of the alternatives on the different criteria are often imprecise and even ill-determined.

MAUT

Multi-attribute utility theory (MAUT) is another MCDM tool that was developed by Keeney and Raiffa [252]. MAUT tool calculates a score for each possible alternative, and the alternative with the highest score is considered to be preferred. MAUT takes into account the decision maker's preferences in the form of the utility function, which is defined over a set of attributes where the utility of each attribute does not have to be linear. The decision-maker can compare all alternatives simultaneously, and have a complete preference ranking over all alternatives. Nonetheless, it not easy to precisely assess the utility function of the decision-maker. Utility values for decision alternatives are determined using single or multi-attribute utility functions. A major advantage of MAUT is its ability to handle uncertainties around the decision environment via incorporating risk preferences into the decision model by using use utility functions. However, it might be difficult for decision-makers to have a clear picture of their risk preferences, and the time and resources needed for the development of the utility function. [253], [252].

5.3.3 Comparison of the MCDM Approaches

The following table 24 summarizes the strengths and weaknesses of each of the above-discussed tool:

Table 18. The strengths and weaknesses of various MCDM approaches

MCDM approach	Strength	Weakness	References
TOPSIS	The tool is simple and able to maintain the same number of steps, regardless of problem size. Less number of pairwise comparisons compared other tools. Support a large number of criteria. Quantitative and qualitative attributes used in the assessment.	No structure approach to weight the criteria. It does not support the relative importance of the distance. does not consider uncertainty in weightings.	[233] [234] [235] [236] [237] [254]
PROMETHEE	The tool is easy to use. It requires fewer inputs and interaction with DM. It deals with qualitative and quantitative criteria.	No structure approach to weight the criteria. It does not show what factors contributed to the best alternative. When a new alternative is introduced, it suffers from the rank reversal problem. It is difficult for the decision-makers to obtain a clear view of the problem and evaluate the results.	[238] [240] [241] [239] [232] [242] [254]
AHP	Easy to use. Break down complex problems, Structure the problem into a hierarchy, the importance of factors is clear. It gives a clearer understanding of the situation. Flexible, intuitive, and checks inconsistencies. It minimizes bias in decision making. It uses expert's judgments. Incorporate quantitative and qualitative data.	Additive aggregation is used. So important information may be lost. The more are the factors, the increase in the number of pairwise comparisons results in experts losing concentration and may provide inaccurate results. The eigenvector and eigenvectors scale of 1-9 may not be easy to follow and a bit confusing. Definitions of the attributes are significant. interdependence between criteria and alternatives may lead to inconsistencies.	[243] [244] [247]
ANP	More generalized approach than AHP. Can solve very complex problems, Independence among elements is not required. Priorities are improved by feedback resulting in more accurate results.	More complex tool than AHP. Time consuming. ANP does not support Uncertainty. Hard to understand the tool by decision-makers. If factors are independents, then it is wiser to use AHP or HDM.	[245] [246] [247] [248] [249]

HDM	Similar AHP. Constant sum scale of 1-99 is easier to use than AHP. it provides more input flexibility and a robust method for consistency analysis	Similar to AHP.	[162] [163] [164]
ELECTRE	Outranking is used. It considers qualitative and quantitative criteria. it takes uncertainty into account.	Time-consuming. Difficult to understand by decision-makers. Needs a lot of input.	[247] [250] [251] [254]
MAUT	The tool takes uncertainty into account. It can incorporate preferences.	It is a difficulty for DM to have a clear picture of their risk preferences and the time and resources needed for the development of the utility function.	[253] [252]

5.3.4 MCDM application in Blockchain

This section presents a sample from the literature that investigates the blockchain technology using MCDM tools as the research methodology. The result of the review shows that there is a lack of literature on blockchain adoption using MCDM tools as a research methodology.

Maden [255] proposed a suitability evaluation of the blockchain-based systems using inputs from experts from a well-known logistics company in Turkey. The study used the Fuzzy Analytical Network Process (Fuzzy ANP) to determine and evaluate the interrelations between the suitability attributes. Also, the proposed method facilitated the prioritization of blockchain-based alternatives.

Öztürk and Yildizbaşi [256] studied the Barriers to implementation of blockchain into supply chain management using an integrated multi-criteria decision-making method: a numerical example. The study discussed the technologic, financial, organizational and environmental challenges that are confronted on a sectoral basis during the integration process fuzzy AHP and fuzzy TOPSIS methods [256].

Farshidi et al. [257] developed MCDM framework for the blockchain platform selection process. The authors designed and implemented a DSS for supporting decision-makers with their technology selection problems in software production. The DSS provided a modeling studio to build such decision models for technology selection problems.

Akın et al. [258] designed an energy ecosystem in the Ethereum Blockchain network, which records all processes from the generation of electricity to the end-user. The aim of this study is to secure the flow of information and money in the process of energy from production to consumption. The study used PROMETHEE in case there is more than one offer suitable for the user request. The weights of the criteria required for this method are determined in the order of the profile of the user.

Frauenthaler et al. [259] introduced a WSM based framework as MCDM to monitor and evaluate several blockchain platforms according to user-defined settings and determines the most appropriate blockchain. The results showed that switching to another blockchain can save costs and enable users to benefit from better performance and a higher level of trust.

Tang et al. [260] present a TOPSIS-based evaluation model to rank public blockchain platforms based on three dimensions: technology, recognition, and activity.

The results show that Bitcoin, Ethereum and EOS are ranked in the top three public blockchains. The most public blockchains lack of popularity was found as well.

Maček and Alagić [261] developed an AHP-based model to evaluate the security characteristics of the Bitcoin cryptocurrency system in comparison to other widely used online transaction systems.

5.4 Other none MCDM Approaches

This section investigates possible approaches besides the MCDM approaches that can be used, such as case study, focus group, interview, brainstorming, cognitive mapping, Delphi method, and statistical survey.

The goal of this research is to build a framework that can be used by healthcare organizations to conduct a readiness assessment of their ability to adopt blockchain technology for the management of the EHR records. Previous answers discussed various MCDM tools with focus on the tool, HDM, used in this research, its process, strengths, and weakness. There are other possible quantitative and qualitative methods that can be used, such as case study, focus group, interview, brainstorming, cognitive mapping, Delphi method, and statistical survey. This section will discuss using case study and survey tools and presents their strengths and weaknesses.

5.4.1 Case Study

The case study can be defined as a "case study is a research strategy which focuses on understanding the dynamics present within single settings." [262]. The case study approach usually combines data collection methods like interviews, questionnaires, and observations. The case study can be used to understand the relationship between the real-life situation and proposed models. The case study method is a great tool as an exploratory tool. The outcome can come in the form of quantitative or qualitative data or even both. Furthermore, the case study can be used in accomplishing various scientific tasks such as testing a theory, provide a description of an event, or even generate a new theory. It is a great fit to investigate contemporary events when the appropriate behavior cannot be manipulated. It is also useful for the preliminary, exploratory stage of a research project, where it can serve as a basis for the development of the 'more structured' tools that are necessary in surveys and experiments [263]. One drawback of the case study methodology is that it has been traditionally viewed as lacking rigor and objectivity when compared with other methods. The generalization of the results drawn from case studies has always been questionable since it depends on a single or limited event(s) under investigation. Also, case studies may produce biased results.

5.4.2 Surveying

The surveying method is one of the most flexible and commonly used research designs in many areas. Surveys are useful for non-experimental descriptive designs that aim to describe reality [264]. Researchers use surveys for collecting data about people for descriptive or predictive purposes [265]. A survey can take many forms, such as questionnaires, one-on-one interviews, panel, mail, or telephone interview. It is an excellent tool for assessing knowledge, attributes, intentions, and behaviors. The sample size of the population is a critical success factor in the surveys. The more the sample size represents the population under investigation, the more reliable results obtained. Surveys often utilize the questionnaire as a data collection tool. The survey method is a quick, easy, flexible, cost-effective way to collect data from large number of people [266]. Another advantage is that it is relatively easy to analyze the surveys and be consistent in how you administer them. However, writing a comprehensive and good survey is not an easy task, as one may think. The collected data may require so much time to clean and prepare them for analysis, and the researcher may get folded with some much data. A bias in response may occur due to the surveys being self-reported. Surveys may face problems with reliability, validity, or misinterpretation of questions.

CHAPTER 6: RESEARCH MODEL DEVELOPMENT AND RESULTS

6.1 The Initial HDM Model

The decision model is based on a comprehensive literature review. A quantitative research method, HDM, is proposed in this research to address the research objectives. The initial HDM model is structured with five main perspectives and several factors within each perspective in order to assess the adoption of the blockchain technology for the management of the EHR. These perspectives are financial, social, technical, organizational, and regulations & legal. Under each perspective, multiple factors are linked to each other. The initial research model will be validated by the experts then finalized. Figure 18 illustrates the initial research model based on the identification of the factors impacting the adoption of blockchain technology for the management of the EHR systems. Tables 20 and 21 below show the definitions for the perspectives and factors. A detailed discussion of the blockchain technology adoption factors has been provided in section 2.8.

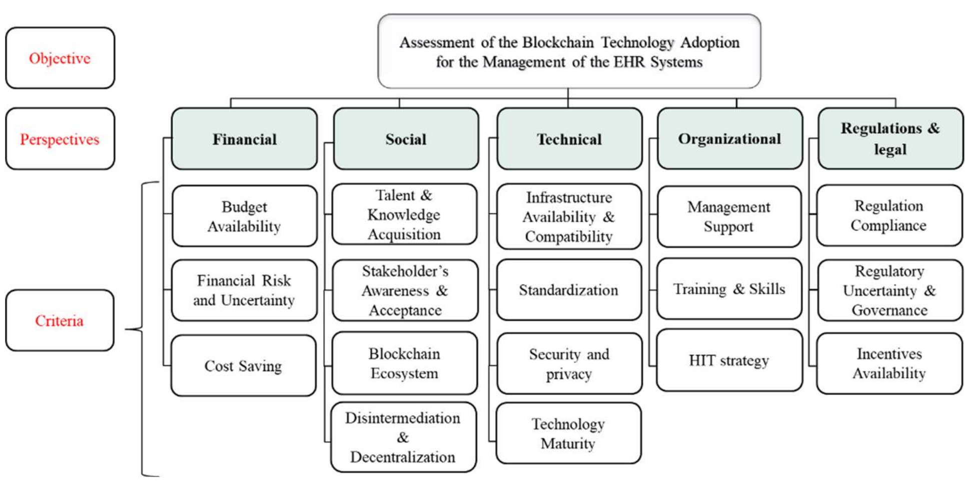

Figure 18. The Initial HDM

6.1.1 Model Perspectives

Table 19. The definitions of the model perspectives

Perspective	Details
Financial Perspective	This perspective captures the financial side of assessing blockchain technology adoption in healthcare organizations. Topics such as Budget availability, Financial Risk and Uncertainty, and Cost-Saving fall under this category.
Social Perspective	This perspective includes Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Business Process.
Technical Perspective	The technical perspective involves challenges unique to blockchain projects due to its nature and its characteristics. This perspective covers Infrastructure & Platform Integration, Standardization, Security and privacy, and Blockchain Maturity and Use Cases.
Organizational Perspective	This perspective covers the organizational aspects such as Management Support, Training & Skills, and HIT strategy alignment. It involves what needs to be considered by management to enable successful and sustainable blockchain adoption within the healthcare organization and overcome adoption barriers.
Legal Perspective	This perspective includes regulatory and legal aspects needed to assess the blockchain adoption in healthcare such as Regulation Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. It involves interaction with external environment issues and entities.

6.1.2 Model Factors

Table 20. HDM Model Factors

Factors	**Details**	**References**
Financial Perspective		
Budget Availability	This factor measures the healthcare organization's ability to dedicate and provide sufficient funds for the blockchain project as well as the budget flexibility with the other associated costs such as operational, maintenance, and expansion.	[17] [80] [83] [105] [144] [148] [146] [147]
Financial Risk and Uncertainty	The number of blockchain projects is limited, and it is hard to be certain of the costs associated with its development and operation. This factor measures the healthcare organization's ability to conduct risk assessments and anticipate various financial costs associated	[17] [80] [83] [148] [146] [147]

	with getting blockchain to work, such as expanding the blockchain network, cost of transactions, maintenance, and scalability.	
Cost Saving	This factor measures the healthcare organizations' ability to have cost-benefits analysis and determined financial saving goals generated from the implementation of the blockchain by utilizing various measurements.	[147] [72] [78] [68] [54] [69] [76] [75] [105]
Social Perspective		
Talent & Knowledge Acquisition	This factor measures the healthcare organization's capabilities and performance to identify, access, acquire external knowledge and talents needed for the development of the blockchain solution for both foundational platform programming and blockchain application development whether the solution is developed in-house or outsourced.	[67] [73] [149] [150] [151] [147] [152] [153] [154]
Stakeholder's Awareness & Acceptance	This factor measures the level of stakeholders' engagement, awareness, and acceptance of the blockchain in terms of adequate realization of its relevance, understanding its potential benefits and challenges, and its existence and impact on the organization's health information technology.	[147] [150] [21] [99] [98]
Blockchain Ecosystem	This factor measures the healthcare organization's effort to work with partners to build an active blockchain ecosystem that includes creating an environment of shared value, defining use cases, developing infrastructure and applications, operating the blockchain network, and solving any additional obstacles.	[17] [83] [146] [147] [72] [69] [21] [97] [155]
Disintermediation & Decentralization	This factor measures healthcare organizations' willingness to adopt new business processes by allowing an auto exchange of data through the distributed ledger and eliminating non-value generating processes or entities.	[17] [146] [72] [54] [69] [67] [21] [97] [155] [43] [46] [48] [53] [71]
Technical Perspective		
Infrastructure Availability & compatibility	The blockchain technology or even any other technology should integrate seamlessly with the existing legacy systems. This factor measures the IT hardware and software infrastructure needed for the blockchain implementation to have sufficient and integrateable infrastructure.	[17] [105] [147]

Standardization	This factor measures the healthcare organization's ability to be clear on what data, size and format can be sent to the blockchain as well as agree on common terms, business logic and business flow as they share access to the same data and apply the same smart contract-enabled business logic.	[54] [80] [83] [101] [148] [146] [147] [144]
Security and Privacy	This factor measures the healthcare organization's ability to identify and foresee the areas of deficiency in the privacy and security of the current practices and in using blockchain to prevent access to healthcare information by unauthorized entities and adherence to privacy regulations.	[46] [63] [71] [104] [146] [147]
Blockchain Maturity	Blockchain maturity means that the technology has been used, tested, and the capabilities have been proven, including use cases, skills availability, and knowledge. Various factors such as regulatory concerns, lack of industry standards, mainstream application deficiency all undermine the technology's innovative potential and create the illusion of an immature technology. This factor measures healthcare organizations' activities and efforts to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects.	[18] [54] [73] [147]
Organizational Perspective		
Management Support	The top management support is essential and a cornerstone in the successful adoption of blockchain technology. This criterion evaluates the support, engagement, and approval of the top management to the blockchain initiative.	[147] [105] [73] [150] [81]
Training and Skills	This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help current staff, technical specialists, and medical staff attain the required level of knowledge or skill related to blockchain solutions as well as expedite the learning process.	[105] [67] [73] [149] [150] [152] [71]
HIT Strategy	It is essential to understand the role of adopting blockchain technology in achieving the higher-level strategic objectives of the healthcare organization and its HIT strategy. Blockchain adoption requires significant changes to the existing system in which companies must strategize the transition. This factor measures the blockchain solution's alignment with the healthcare organization's IT strategy and objective of achieving a higher quality of care.	[17] [21] [72] [105] [147]
Regulations & legal Perspective		

Regulation Compliance	This factor measures the healthcare organization's effort to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with blockchain technology such as HIPAA, PHI, data sharing, and technological laws in order to satisfy the compliance aspect, preserve data privacy, and adherence to privacy regulations.	[17] [149] [155]
Regulatory Uncertainty & Governance	This factor investigates the clarity and maturity of the consensus mechanism, access control, smart contracts, the rules that administrate the blockchain network, what data to be stored on-chain and off-chain as well as the flexibility to adapt to and address new changes in the regulatory landscape by assessing the legislative changes and take timely actions.	[73] [80] [83] [84] [140] [148] [146] [147] [155] [156] [159] [160] [161]
Incentives Availability	This factor examines the organization's ability to work with partners and government officials to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the blockchain network.	[17] [83] [80] [85] [91]

6.2 Expert panels formation

An extensive discussion on the expert's characteristics, identification and selection, and panels formation has been provided in chapter 5. The final number of experts, their characteristics, and roles through the research are shown below.

Table 21. Expert panels formation and size

Panel #	Role	Tool	Size
P1	Validate the perspectives	Qualtrics Survey	13
P2 F	Validate the factors under the financial perspective	Qualtrics Survey	13
P3 S	Validate the factors under the social perspective	Qualtrics Survey	13
P4 T	Validate the factors under the technical perspective	Qualtrics Survey	14
P5 O	Validate the factors under the organizational perspective	Qualtrics Survey	13
P6 L	Validate the factors under the regulations & legal perspective	Qualtrics Survey	9
P7	Quantify the perspectives	Qualtrics Survey + ETM HDM software	9
P8 F	Quantify the factors under the financial perspective	Qualtrics Survey + ETM HDM software	8
P9 S	Quantify the factors under the social perspective	Qualtrics Survey + ETM HDM software	10

P10 T	Quantify the factors under the technical perspective	Qualtrics Survey + ETM HDM software	11
P11 O	Quantify the factors under the organizational perspective	Qualtrics Survey + ETM HDM software	9
P12 L	Quantify the factors under the regulations & legal perspective	Qualtrics Survey + ETM HDM software	7

Table 22. Experts' backgrounds

Expert	Title	Expert	Title
Expert 1	Blockchain Developer & System Engineer	Expert 35	Computer Science Engineer (Tech Firm)
Expert 2	Blockchain Lawyer	Expert 36	Growth, Partnerships, New Ventures, and Business Transformation Catalyst (Financial Blockchain based firm)
Expert 3	Professor and Blockchain Consultant	Expert 37	BSS Senior Consultant (Blockchain-based health solution)
Expert 4	Research Scholar	Expert 38	Blockchain in bioinformatics expert & Business Intelligence Analyst
Expert 5	Software Engineer	Expert 39	CEO and Affiliate Relations Manager (Blockchain based financial firm)
Expert 6	Blockchain Developer	Expert 40	Technology Marketing Specialist (Blockchain based firm)
Expert 7	Senior Blockchain Developer & Advisor	Expert 41	CTO and Director of Consulting & Tech Chair (Blockchain Consortium & Consulting)
Expert 8	Software Engineer	Expert 42	Health Hospitality and Blockchain Analyst
Expert 9	Digital Health Expert	Expert 43	Professor (IT)
Expert 10	Director – Blockchain & DeFi	Expert 44	President (Blockchain Alliance in Transportation)
Expert 11	Blockchain Developer and Technical Project Manager	Expert 45	CEO, Technical Director, and Blockchain Consultant and Experts (Consulting firm)
Expert 12	CEO and app developer (Blockchain Medical Records)	Expert 46	Manager (Deloitte - tech & blockchain consultancy)
Expert 13	Blockchain Software Architect (Project, Product Development)	Expert 47	Junior Software Engineer & Blockchain Developer
Expert 14	CEO & Infrastructure Architect Consulting (IT & Data Solutions)	Expert 48	CEO and Clinical Research Scientist
Expert 15	Blockchain Researcher and Project manager (Blockchain Center)	Expert 49	CTO & Senior advisor (Blockchain consultancy firm)
Expert 16	CEO (EHR-Blockchain company)	Expert 50	Cognitive Solutions E&U industry leader (IBM)
Expert 17	Blockchain Go-to-Market Offering Manager (Cloud Integration-Blockchain)	Expert 51	Blockchain and Innovation Consultant & Head of Digital Marketing and Community
Expert 18	Founder and consultant (blockchain strategy and consultation)	Expert 52	DLT & Blockchain Consultant

Expert 19	Podcaster at Health Unchained & Blockchain Technical Account Manager	Expert 53	Blockchain investment expert
Expert 20	Program Director and Worldwide Blockchain Technical Architect Leader	Expert 54	Director/Blockchain Subject Matter expert (Blockchain development and consultancy firm)
Expert 21	Blockchain Analyst	Expert 55	Blockchain IOT Entrepreneur and Angel Investor
Expert 22	Merge and acquisition Analyst (Blockchain Ventures Firm)	Expert 56	Senior Blockchain Architect
Expert 23	Senior Manager (Blockchain based financial company)	Expert 57	Managing Director (Tech company & Blockchain association)
Expert 24	Máster Blockchain Aplicado	Expert 58	Senior Litigation Attorney (regulatory compliance for emerging technology focus)
Expert 25	Professor and Chief Scientific officer at Blockchain-Healthcare based consultancy firm	Expert 59	Attorney at Law & Operations Associate (emerging tech focus)
Expert 26	Chief Collaboration Officer and Remote Project Lead (Blockchain based company)	Expert 60	Director (Technology & digital innovation Firm)
Expert 27	Consultant and Clinical Informatics	Expert 61	PhD Researcher (Technology lab)
Expert 28	Sr. Engineer and Solution Architect	Expert 62	CEO & Digital Transformation Leader (technology consultancy firm)
Expert 29	Cloud Solutions Team Leader and Architect	Expert 63	Software Engineer (Blockchain Engineer)
Expert 30	Blockchain Engineer	Expert 64	Blockchain Research Analyst
Expert 31	Blockchain Research Scientist and Technical Representative	Expert 65	Blockchain Technical Leader
Expert 32	Emerging Technology Consultant and Managing Director (Blockchain consultancy)	Expert 66	CTO and Advisor (Software Company & national Blockchain committee member)
Expert 33	Director, Health Information Exchange, and Advisor	Expert 67	Technology and Blockchain Consultant & Project Manager (Technology Firm)
Expert 34	Presales Architect & Go-to-Market Strategy (Blockchain firm)	Expert 68	Business Consultant & Enterprise Blockchain Analyst

In order to satisfy the research objective and ensure generalizable model, experts were selected carefully and following series of steps as described in chapter 5. The following two tables (Table 23 and 24) show the experts' categories and experts' types.

Table 23. Experts' Categories

Categories	# Experts

Senior Manager	20
Middle Manager	21
Technical/Legal/Business Specialists	20
Academia/Researcher	7
Total	68

Figure 19. Experts' Categories

Table 24. Expertise Type

Expertise Type	# Experts
Engineer/Developer	20
Project Manager	11
Consultant	14
Academia/Researcher	7
Health Expert	8
Business Specialist	13
Legal Specialists	3
Top Management	19

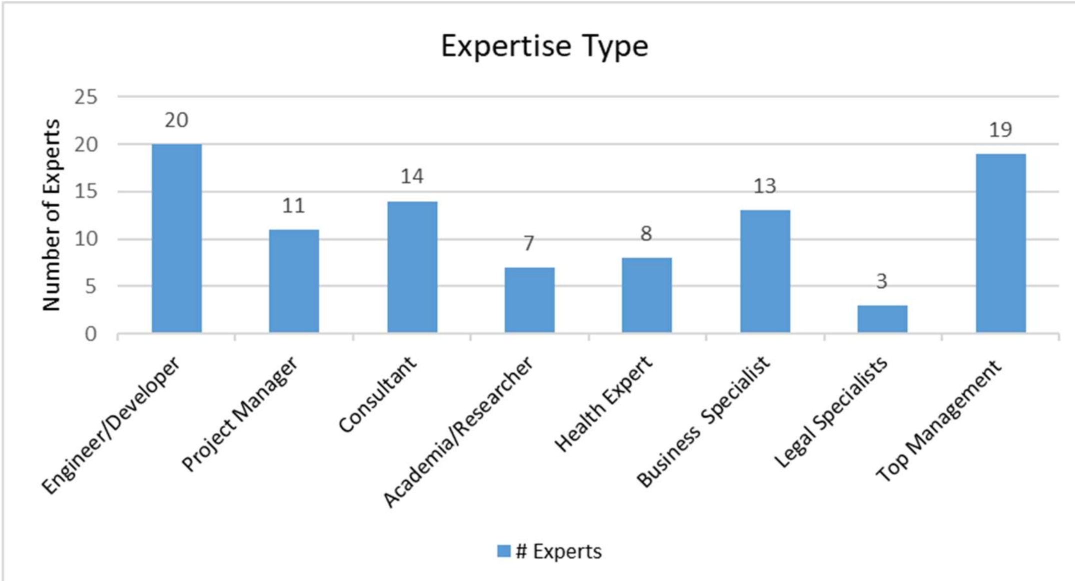

Figure 20. Expertise Type

The research model has the opportunity to be generalized and used in different regions around the world. Therefore, the experts were selected from different parts of the world, such as USA, India, Spain, UAE, Australia, and many other countries.

Table 25. Experts by Country

Location	Expert Count
USA	15
India	8
Spain	5
UAE	4
Australia	3
Other	33
Total	**68**

6.3 Model Validation and Quantification

Experts were invited to participate in the research using email and Linkedin.com. Upon accepting the invitations, experts were sent details about the study and the link to the surveys. Qualtrics surveys were designed to capture experts' judgments for the validation and quantification stages as well as one-on-one interviews with some of the experts. A sample invitation letter is shown in Appendix A.

6.3.1 Model Validation

The content validity refers to the model contents' ability to represent all relevant aspects pertaining to the research topic properly. The validation of the model constructs ensures that the most important factors have been included in the model, and the model best represents reality. blockchain experts have been invited to validate the model perspectives, factors under each perspective, desirability metrics, and the results of the model quantification. The experts chosen to validate the model have in-depth knowledge in blockchain technology, come from different backgrounds, and possess different experiences. The goal of conducting the validation process is to ensure that the essential elements influencing the blockchain adoption have been captured and ensure that the model is valid for the real application. Special attention should be given to the validation process to ensure reliable results and a generalizable model that can be used by different organizations and different industries.

The experts were asked to validate each item, and if at least two/third of the expert panel's members approve that specific factor, then it is kept in the model [177] [178]. The experts are also given the opportunity to suggest new factors that they believed essential to add to the model. In this phase, the experts were sent an invitation email to participate in the validation phase. They were explained what is expected from them and accompanied with a summary of the research and factors' definitions. The validation was done using Qualtrics software. The surveys involved a yes and no question for each criterion where yes means that the expert believes the factor should be included in the model to assess the blockchain adoption in healthcare. No means that the factor is not essential to have in the model.

For the validation phase, 30 experts have participated and were distributed across 6 panels, as shown below. Appendix B shows the perspectives and factors validation survey using Qualtrics software.

Table 26. The expert panels' roles in the validation phase

Panel	Role	Tool	Size
P1	Validate the perspectives	Qualtrics Survey	13
P2 S	Validate the factors with the financial perspective	Qualtrics Survey	13
P3 S	Validate the factors with the social perspective	Qualtrics Survey	13
P4 T	Validate the factors with the technical perspective	Qualtrics Survey	14
P5 O	Validate the factors with the organizational perspective	Qualtrics Survey	13
P6 L	Validate the factors with the regulations & legal perspective	Qualtrics Survey	9

The following table shows the list of experts and their participation in the validation process.

Table 27. Experts distribution across the validation panels

Expert	Title	P1	P2 F	P 3 S	P 4 T	P 5 O	P 6 L
Expert 1	Blockchain Developer & System Engineer				Y		
Expert 2	Blockchain Lawyer			Y			Y
Expert 3	Professor and Blockchain Consultant	Y		Y		Y	
Expert 4	Research Scholar	Y		Y		Y	
Expert 5	Software Engineer				Y	Y	
Expert 6	Blockchain Developer	Y		Y	Y		
Expert 7	Senior Blockchain Developer & Advisor		Y		Y	Y	
Expert 8	Software Engineer				Y		
Expert 9	Digital Health Expert	Y	Y			Y	Y

Expert 10	Director		Y				Y
Expert 11	Blockchain Developer and Technical Project Manager				Y	Y	
Expert 12	CEO and app developer	Y	Y			Y	
Expert 13	Blockchain Software Architect (Project, Product Development)		Y		Y		
Expert 14	CEO & Infrastructure Architect Consulting	Y	Y		Y		Y
Expert 15	Blockchain Researcher and Project manager			Y			Y
Expert 16	CIO	Y	Y	Y	Y		
Expert 17	Blockchain Go-to-Market Offering Manager (Cloud Integration- Blockchain)	Y	Y				
Expert 18	Founder and consultant					Y	Y
Expert 19	Technical Account Manager			Y		Y	
Expert 20	Program Director and Worldwide Blockchain Technical Architect Leader	Y	Y	Y	Y	Y	Y
Expert 21	Blockchain Analyst			Y			
Expert 22	Merge and Acquisition Analyst		Y				
Expert 23	Senior Manager	Y				Y	
Expert 24	Máster Blockchain Aplicado				Y		
Expert 25	Professor and Chief Scientific officer	Y	Y		Y	Y	Y
Expert 26	Chief Collaboration Officer and Remote Project Lead	Y	Y	Y			
Expert 27	Consultant and Clinical Informatics	Y		Y			
Expert 28	Sr. Engineer and Solution Architect			Y			
Expert 29	Cloud Solutions Team Leader and Architect				Y		
Expert 30	Blockchain Engineer		Y	Y	Y	Y	Y
Total		**13**	**13**	**13**	**14**	**13**	**9**

Pre-Validation HDM Model

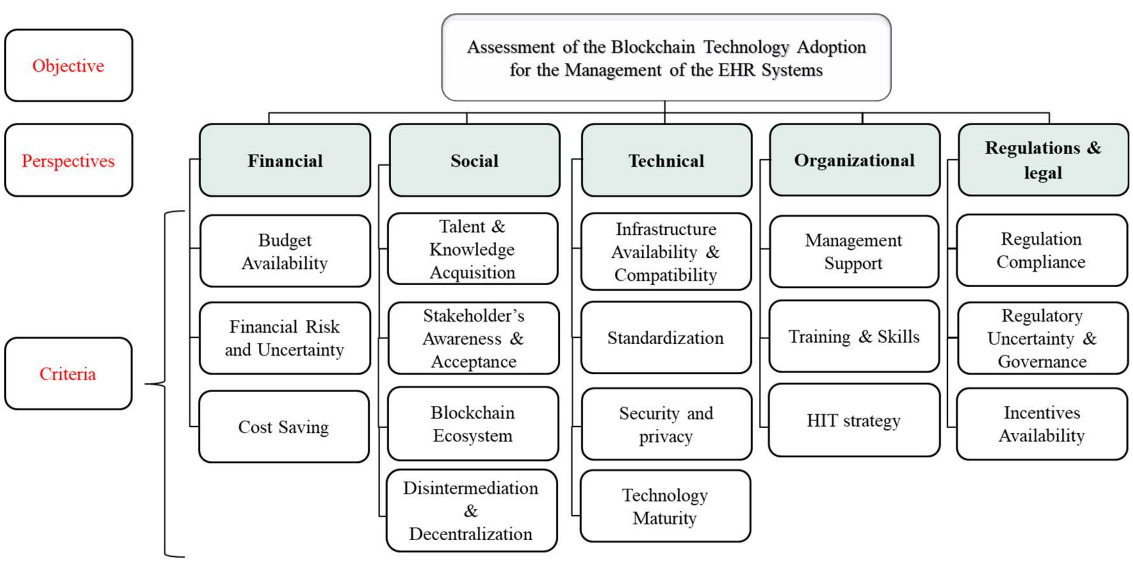

Figure 21. The Pre-Validation HDM Model

The following section shows the results of the validation phase.

Perspectives Validation

Panel 1: The first panel consisted of 13 experts. All the experts agreed that the financial, social, technical, organization, and regulations & legal are significant perspectives for the assessment of the blockchain technology adoption for the management of the EHR systems.

All perspectives were approved by more than 67% of experts from the P1 panel. Table 26 shows a summary of P1 panel validation results, and table 27 includes details about the experts and their individual judgment. Figure 20 shows the perspectives validation results.

Table 28. Perspectives Validation Summary by P1 Panel

Perspectives	Response		Validation %
	Yes	No	
Financial	13	0	100%
Social	11	2	85%
Organizational	12	1	92%
Technical	11	2	85%
Regulations & Legal	13	0	100%

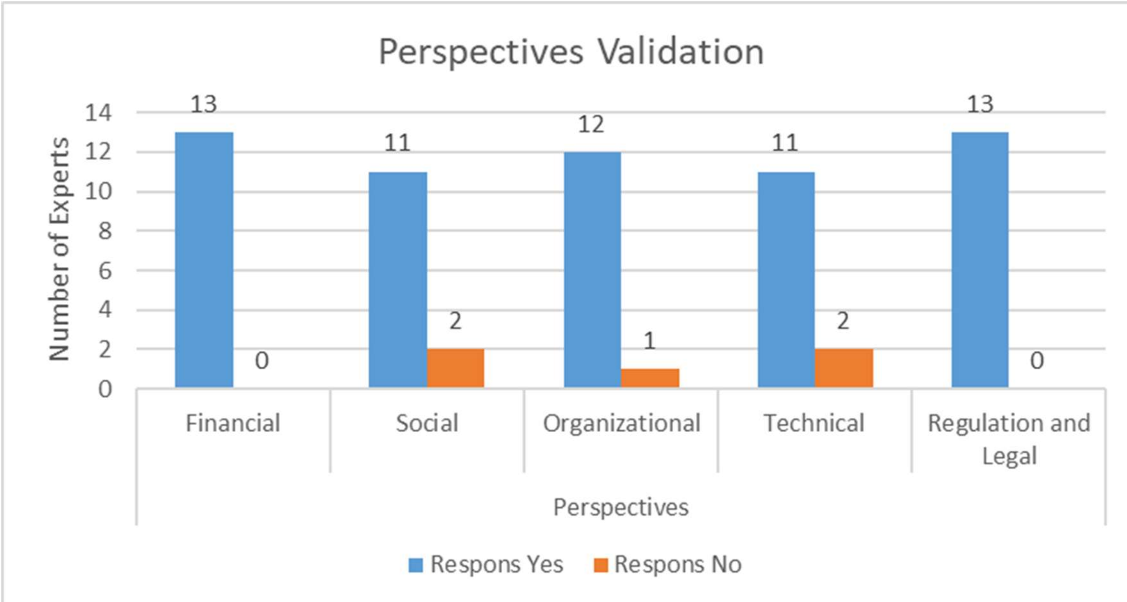

Figure 22. Perspectives validation by P1 Panel

Table 29. Perspectives Detailed Validation by P1 Panel

	Perspective				
Expert	**Financial**	**Social**	**Organizational**	**Technical**	**Regulations & Legal**
Expert 3	Y	Y	Y	Y	Y
Expert 4	Y	Y	Y	Y	Y
Expert 6	Y	Y	N	Y	Y
Expert 9	Y	Y	Y	Y	Y
Expert 12	Y	Y	Y	Y	Y
Expert 14	Y	Y	Y	Y	Y
Expert 16	Y	Y	Y	N	Y
Expert 17	Y	Y	Y	Y	Y
Expert 20	Y	N	Y	Y	Y
Expert 23	Y	Y	Y	Y	Y
Expert 25	Y	Y	Y	Y	Y
Expert 26	Y	N	Y	N	Y
Expert 27	Y	Y	Y	Y	Y
Total Approved	**13**	**11**	**12**	**11**	**13**

Factors under each perspective validation

Panel 2-6: The majority of the experts agreed that the factors under financial, social, technical, organization, and regulations & legal perspectives are significant for the assessment of the blockchain technology adoption for the management of the EHR systems.

The following tables and figures show the validation for the factors under each perspective:

Financial Perspective Validation:

Table 30. Financial-related Factors Validation Summary by P2 F Panel

Perspective	Factor	Response		Validation%
		Yes	No	
Financial	Budget Availability	12	1	92%
	Financial Risk & Uncertainty	12	1	92%
	Cost Saving	12	1	92%

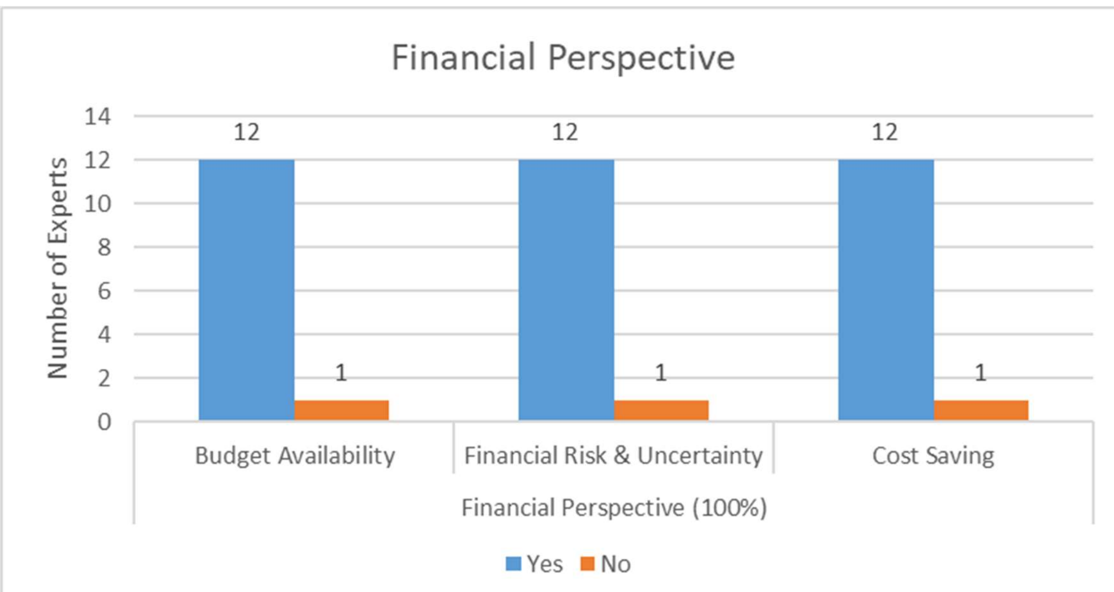

Figure 23. Financial Perspective Validation by P2 F Panel

Table 31. Financial-related Factors Detailed Validation by P2 F Panel

Expert	Budget Availability	Financial Risk & Uncertainty	Cost Saving
Expert 7	Y	Y	Y
Expert 9	Y	Y	Y
Expert 10	Y	Y	Y

Expert 12	Y	Y	Y
Expert 13	Y	Y	Y
Expert 14	Y	Y	Y
Expert 16	Y	Y	Y
Expert 17	Y	Y	Y
Expert 20	Y	N	N
Expert 22	Y	Y	Y
Expert 25	Y	Y	Y
Expert 26	N	Y	Y
Expert 30	Y	Y	Y
Total Approved	**12**	**12**	**12**

Social Perspective Validation:

Table 32. Social-related Factors Validation Summary by P3 S Panel

Perspective	Factor	Response		Validation%
		Yes	No	
Social	Talent & Knowledge acquisition	11	2	85%
	Stakeholder's Awareness & Acceptance	12	1	92%
	Blockchain Ecosystem	12	1	92%
	Disintermediation & Decentralization	10	3	77%

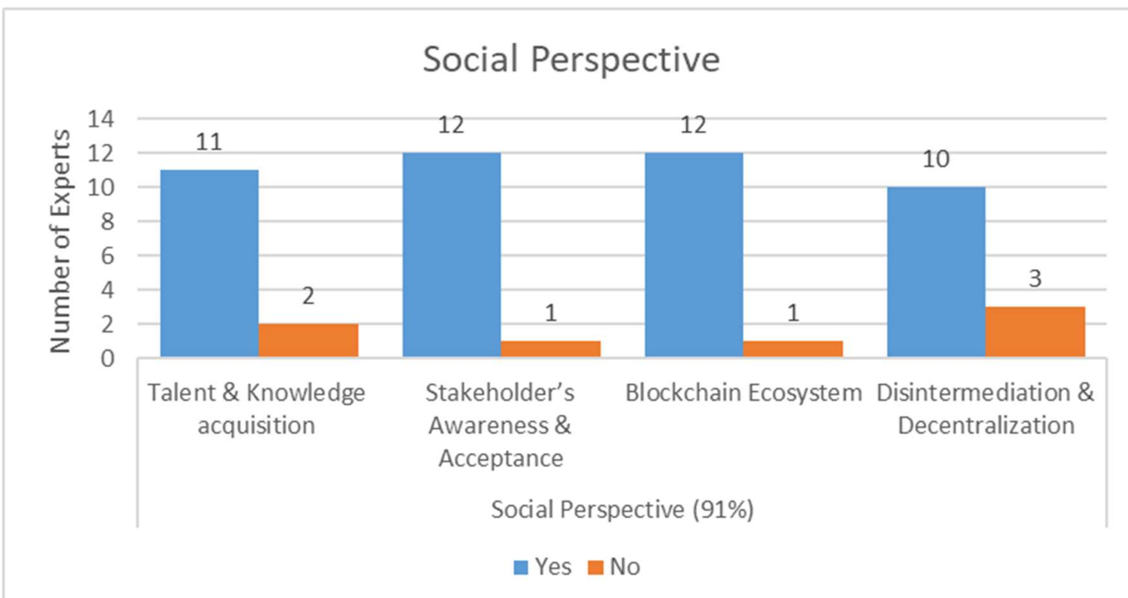

Figure 24. Social Perspective Validation by P3 S Panel

Table 33. Social-related Factors Detailed Validation by P3 S Panel

Expert	Talent & Knowledge acquisition	Stakeholder's Awareness & Acceptance	Blockchain Ecosystem	Disintermediation & Decentralization
Expert 2	Y	Y	Y	Y
Expert 3	Y	Y	Y	N
Expert 4	Y	Y	Y	Y
Expert 6	Y	Y	Y	Y
Expert 15	Y	Y	N	Y
Expert 16	N	Y	Y	Y
Expert 19	Y	Y	Y	Y
Expert 20	Y	N	Y	N
Expert 21	Y	Y	Y	Y
Expert 26	N	Y	Y	N
Expert 27	Y	Y	Y	Y
Expert 28	Y	Y	Y	Y
Expert 30	Y	Y	Y	Y
Total Approved	**11**	**12**	**12**	**10**

Technical Perspective Validation:

Table 34. Technical-related Factors Validation Summary by P4 T Panel

Perspective	Factor	Response		Validation%
		Yes	No	
Technical	Infrastructure Availability and Compatibility	12	2	86%
	Standardization	12	2	86%
	Security and Privacy	14	0	100%
	Blockchain Maturity	12	2	86%

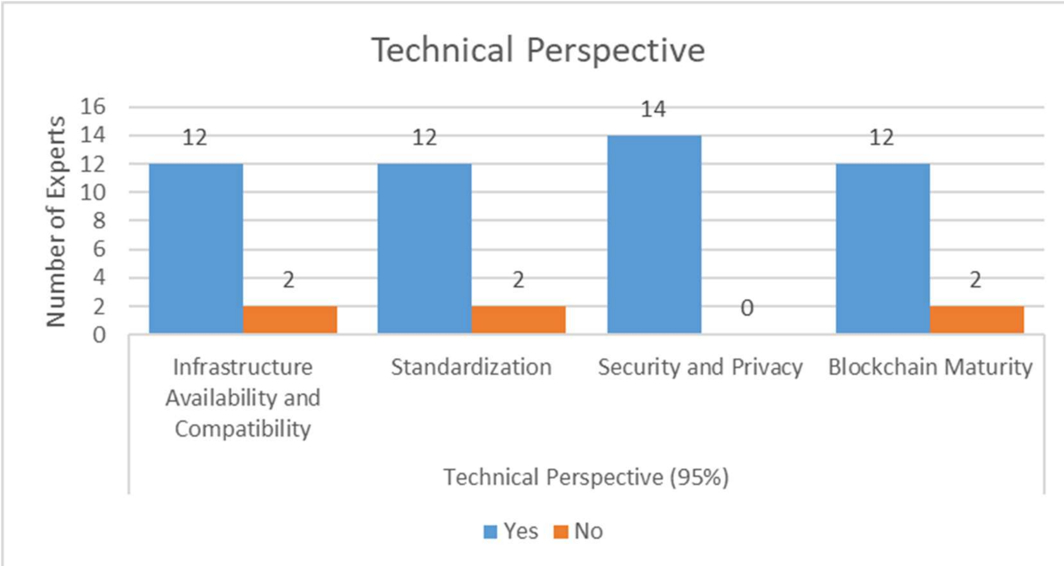

Figure 25. Technical Perspective Validation by P4 T Panel

Table 35. Technical-related Factors Detailed Validation by P4 T Panel

Expert	Infrastructure Availability and Compatibility	Standardization	Security and Privacy	Blockchain Maturity
Expert 1	Y	Y	Y	Y
Expert 5	Y	Y	Y	Y
Expert 6	Y	N	Y	N
Expert 7	Y	Y	Y	Y
Expert 8	Y	Y	Y	Y
Expert 11	Y	Y	Y	Y
Expert 13	Y	Y	Y	Y
Expert 14	Y	Y	Y	Y
Expert 16	Y	Y	Y	Y
Expert 20	N	Y	Y	N
Expert 24	Y	Y	Y	Y
Expert 25	N	Y	Y	Y
Expert 29	Y	Y	Y	Y
Expert 30	Y	N	Y	Y
Total Approved	**12**	**12**	**14**	**12**

Organizational Perspective Validation:

Table 36. Organizational-related Factors Validation Summary by P5 O Panel

Perspective	Factor	Response		Validation%
		Yes	No	
Organizational	Management Support	13	0	100%
	Training and Skills	9	4	69%
	HIT Strategy	12	1	92%

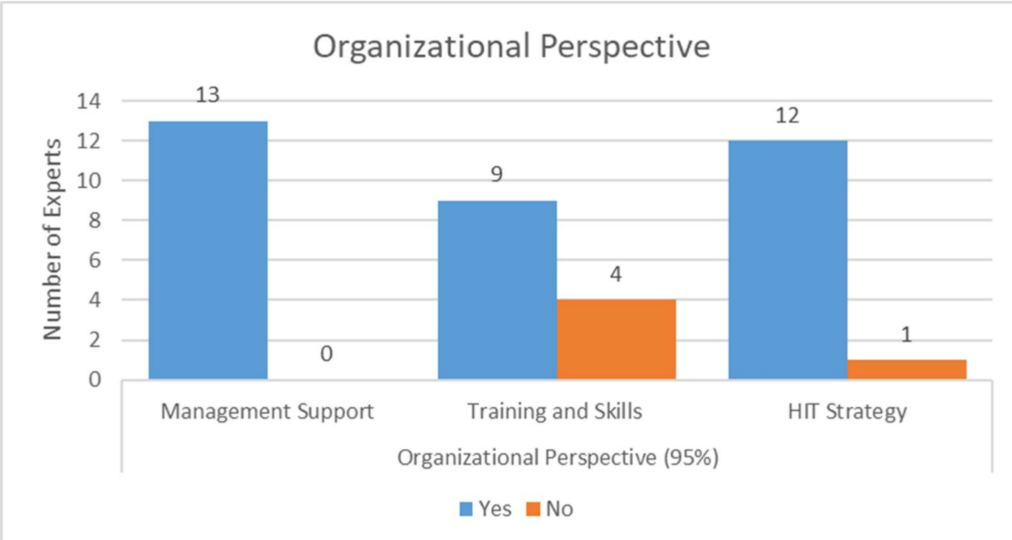

Figure 26. Organizational Perspective Validation by P5 O Panel

Table 37. Organizational -related Factors Detailed Validation by P5 O Panel

Expert	Management Support	Training and Skills	HIT Strategy
Expert 3	Y	Y	Y
Expert 4	Y	Y	Y
Expert 5	Y	N	Y
Expert 7	Y	Y	Y
Expert 9	Y	Y	Y
Expert 11	Y	Y	Y
Expert 12	Y	N	Y
Expert 18	Y	Y	Y
Expert 19	Y	Y	Y
Expert 20	Y	Y	N
Expert 23	Y	N	Y
Expert 25	Y	N	Y
Expert 30	Y	Y	Y
Total Approved	**13**	**9**	**12**

Regulations & Legal Perspective Validation:

Table 38. Regulations & Legal-related Factors Validation Summary by P5 L Panel

Perspective	Factor	Response		Validation%
		Yes	No	
Regulations & legal	Regulation Compliance	9	0	100%
	Regulatory Uncertainty & Governance	8	1	89%
	Incentives Availability	6	3	67%

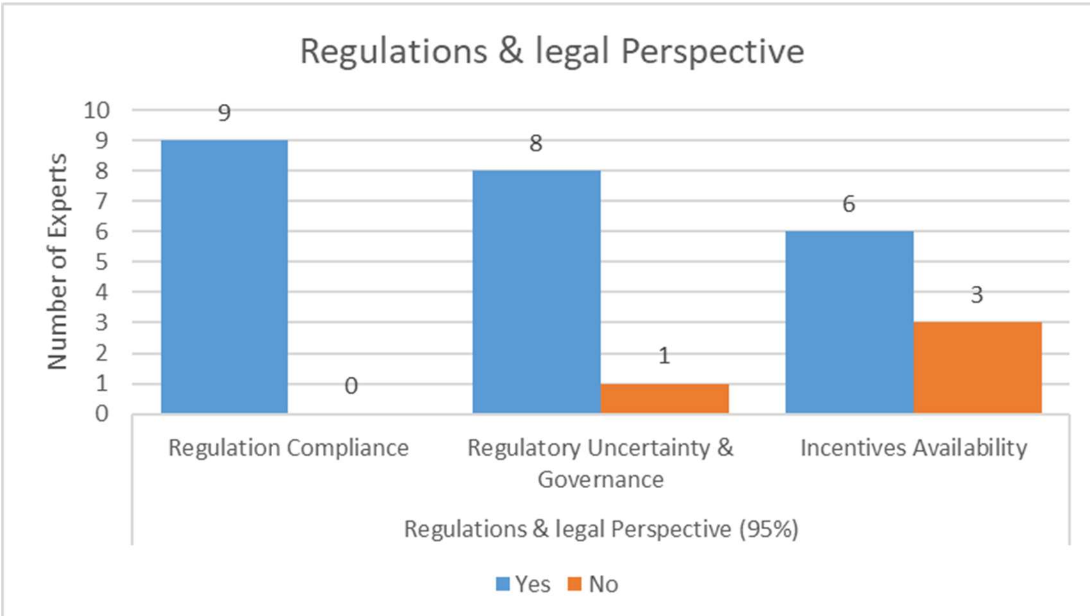

Figure 27. Regulations & Legal Perspective Validation by P5 L Panel

Table 39. Regulations & Legal-related Factors Detailed Validation by P5 L Panel

Expert	Regulation Compliance	Regulatory Uncertainty & Governance	Incentives Availability
Expert 2	Y	Y	N
Expert 9	Y	Y	Y
Expert 10	Y	Y	Y
Expert 14	Y	Y	Y
Expert 15	Y	Y	N
Expert 18	Y	Y	Y
Expert 20	Y	Y	Y
Expert 25	Y	N	N
Expert 30	Y	Y	Y
Total Approved	**9**	**8**	**6**

The overall validation of the factors under each perspective:

Table 40. The Final HDM Model Validation

Perspectives and Factors		
Perspective	**Factor**	**Validation%**
Financial (100%)	Budget Availability	**92%**
	Financial Risk & Uncertainty	**92%**
	Cost Saving	**92%**
Social (91%)	Talent & Knowledge acquisition	**85%**
	Stakeholder's Awareness & Acceptance	**92%**
	Blockchain Ecosystem	**92%**
	Disintermediation & Decentralization	**77%**
Technical (95%)	Infrastructure Availability and Compatibility	**100%**
	Standardization	**69%**
	Security and Privacy	**92%**
	Blockchain Maturity	**86%**
Organizational (95%)	Management Support	**86%**
	Training and Skills	**100%**
	HIT Strategy	**86%**
Regulations & legal Perspective (95%)	Regulation Compliance	**100%**
	Regulatory Uncertainty & Governance	**89%**
	Incentives Availability	**67%**

Changes to the initial Model

Based on the expert's validation, feedback, and discussion, some initial model changes have been made. Some factors have been redefined and put into perspective to better illustrate their definitions, such as regulation uncertainty & governance, standardization, and Disintermediation & Decentralization. The factors Disintermediation & Decentralization, Infrastructure Availability & Compatibility, and Blockchain Maturity have been renamed and expanded in their scoop. The following section reflects the new changes.

Post-Validation HDM Model:

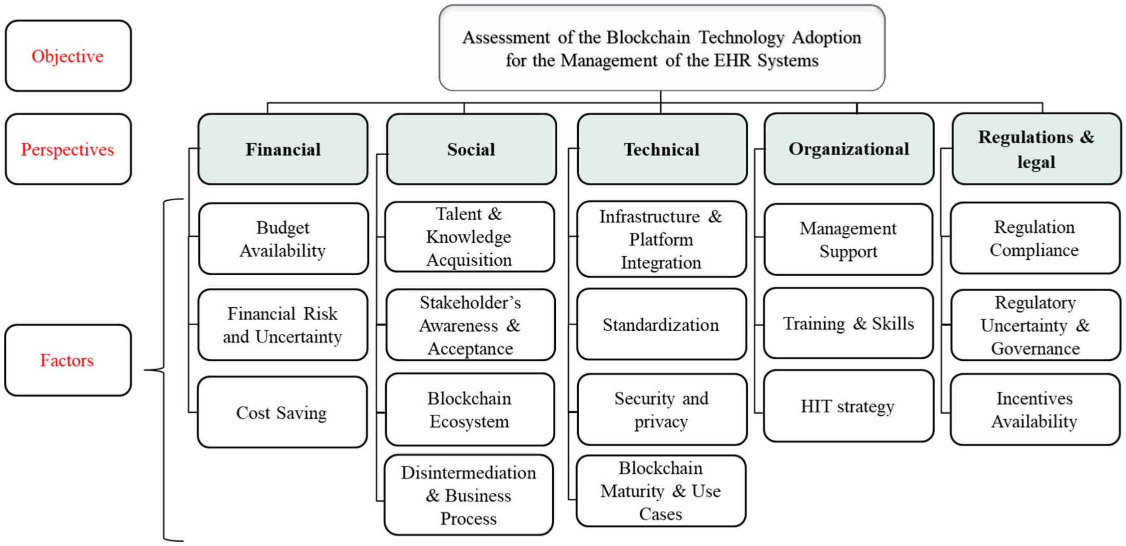

Figure 28. Post-Validation HDM Model

Model Definition Post-validation

Table 41. Post-validation HDM Perspectives' Definitions

Perspective	Details
Financial Perspective	This perspective captures the financial side of assessing blockchain technology adoption in healthcare organizations. Topics such as Budget availability, Financial Risk and Uncertainty, and Cost-Saving fall under this category.
Social Perspective	This perspective includes Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Business Process.
Technical Perspective	The technical perspective involves the unique challenges to blockchain projects due to its nature and its characteristics. This perspective covers Infrastructure & Platform Integration, Standardization, Security and privacy, and Blockchain Maturity and Use Cases.
Organizational Perspective	This perspective covers the organizational aspects such as Management Support, Training & Skills, and HIT strategy alignment. Management needs to be considered to enable successful and sustainable blockchain adoption within the healthcare organizations and overcome adoption barriers.
Legal Perspective	This perspective includes regulatory and legal aspects needed to assess the blockchain adoption in healthcare, such as Regulation Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. It involves interaction with external environment issues and entities.

Table 42. Post-validation HDM factors' Definitions

Factors	Details	References
Financial Perspective		
Budget Availability	This factor measures the ability of the healthcare organization to dedicate and provide sufficient funds for the blockchain project as well as the budget flexibility with the other associated costs such as operational, maintenance, and expansion.	[17] [80] [83] [105] [144] [148] [146] [147]
Financial Risk and Uncertainty	The number of blockchain projects are limited, and it is hard to be certain of the costs associated with its development and operation. This factor measures the ability of the healthcare organization to conduct risk assessments and anticipate various financial costs associated with getting blockchain to work, such as expanding the blockchain network, cost of transactions, maintenance, and scalability.	[17] [80] [83] [148] [146] [147]
Cost Saving	Many healthcare organizations are waiting for proven and clear return on investment to move on in adopting blockchain solutions and join blockchain networks. ROI and cost reduction could come from the automation of intense human actions, elimination of unnecessary intermediaries or process, increased efficiency, reduce lag times (claims and clinical data), record duplication reduction, and data collection time and effort. This factor measures the ability of the healthcare organizations to have cost-benefits analysis and determined financial saving goals generated from the implementation of the blockchain by utilizing various measurements.	[147] [72] [78] [68] [54] [69] [76] [75] [105]
Social Perspective		
Talent & Knowledge Acquisition	This factor measures the healthcare organization's capabilities and performance to identify, access, acquire external knowledge and talents needed for the development of the blockchain solution for both foundational platform programming and blockchain application development whether the solution is developed in-house or outsourced.	[67] [73] [149] [150] [151] [147] [152] [153] [154]
Stakeholder's Awareness & Acceptance	This factor measures the level of stakeholder's engagement, awareness, and acceptance of the blockchain in terms of adequate realization of its relevance, understanding its potential benefits and challenges, and its existence and impact on the organization's health information technology.	[147] [150] [21] [99] [98]

Blockchain Ecosystem	This factor measures the effort of the healthcare organization to work with partners to build an active blockchain ecosystem that includes creating an environment of shared value, defining use cases, developing infrastructure and applications, operating the blockchain network, and solving any additional obstacles.	[17] [83] [146] [147] [72] [69] [21] [97] [155]
Disintermediation & Business Process	This factor measures the willingness of the healthcare organizations to adopt new business process by allowing an auto exchange of data through distributed ledger and eliminating nonvalue generating processes or entities.	[17] [146] [72] [54] [69] [67] [21] [97] [155] [43] [46] [48] [53] [71]
Technical Perspective		
Infrastructure & Platform Integration	The blockchain technology or even any other technology should be able to integrate seamlessly with the existing legacy systems. The healthcare organization should have sufficient and integrateable infrastructure in terms of hardware and software to support the implementation. This factor measures the integrability of the blockchain platform into the current infrastructure seamlessly.	[17] [105] [147]
Standardization	This factor measures the ability of the healthcare organization to be clear on what data, size and format can be sent to the blockchain as well as agree on common terms, business logic and business flow as they share access to the same data and apply the same smart contract-enabled business logic. Also, healthcare organization should have the willingness and flexibility to collaborate to further develop and recognize standard-setting body to progress blockchain related standards as well as work with blockchain vendors to offer compatible software.	[54] [80] [83] [101] [148] [146] [147] [144]
Security and Privacy	This factor measures the ability of the healthcare organization to mitigate privacy risks, how to use blockchain to improve privacy, discover to what extent blockchain provides security, manage new security risks, and identify the areas of deficiency in the privacy and security of using blockchain for the management of the EHR in order to prevent access to healthcare information by unauthorized entities that can harm patient's data.	[46] [63] [71] [104] [146] [147]
Blockchain Maturity & Use Cases	Blockchain maturity means that the technology has been used, tested, and the capabilities have been proven that includes use cases, skills availability, and knowledge. This factor measures the activities and efforts of the healthcare organizations to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects. The activities that ensure the	[18] [54] [73] [147]

	maturity of the technology understanding include understand the need for blockchain, translate it in technical requirements and develop it while keeping the product owner well informed, a specialized team with business experts, concept designers and development team specialized in blockchain is highly required.	
Organizational Perspective		
Management Support	The top management support is an essential and a cornerstone in the successful blockchain technology adoption. This factor evaluates the level of support, engagement, and approval of the top management to the blockchain initiative.	[147] [105] [73] [150] [81]
Training and Skills	This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help existing technical specialists involved with the blockchain adoption, implementation, and maintenance attain the required level of knowledge or skill related to blockchain solution as well as expedite the learning process. This includes data modeling and normal system availability as well as whether the solution is developed in-house or outsourced.	[105] [67] [73] [149] [150] [152] [71]
HIT Strategy	It is essential to understand the role of adopting blockchain technology in achieving the higher-level strategic objectives of the healthcare organization and its HIT strategy. Blockchain adoption requires significant changes to the existing system in which organizations must strategize the transition. This factor measures the alignment of the blockchain solution with the healthcare organization's IT strategy and objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem.	[17] [21] [72] [105] [147]
Regulations & legal Perspective		
Regulation Compliance	This factor measures the healthcare organization's effort to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with blockchain technology such as HIPAA, PHI, data sharing, and technological laws in order to satisfy the compliance aspect, preserve data privacy. and adherence to privacy regulations.	[17] [149] [155]
Regulatory Uncertainty & Governance	This factor investigates the clarity and maturity of the consensus mechanism, access control, smart contracts, the rules that administrate the blockchain network, what data to be stored on-chain and off-chain as well as the flexibility to adapt to and address new changes in the regulatory landscape by assessing the legislative changes and take timely actions.	[73] [80] [83] [84] [140] [148] [146] [147] [155] [156]

		[159] [160] [161]
Incentives Availability	This factor examines the ability of the healthcare organization to work with partners and government officials as possible to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the blockchain network.	[17] [83] [80] [85] [91]

6.3.2 Model Quantification

In the HDM, the subjective judgments are expressed in pairwise comparisons, which then converted to relative weights in ratio scale. The experts in this phase evaluate the perspectives and factors of the hierarchy by conducting pairwise comparisons, with a constant-sum measurement scale (1–99 scale) for each two decision factors. The number of pairwise comparisons can be presented by the formula: PWC = N(N-1)/2 meaning that since we have five perspectives that the expert will need to compare against each other, then the number of pairwise comparisons the expert is required to conduct is 10. The methodology can be used for quantifying the judgment of a single decision-maker, or multiple decision-makers [169] [174]. HDM evaluates and assigns numerical values to the perspectives and factors. Each factor will have a global weight and local weight within its parent perspective or category. Thereby bringing clarity to the diverse options available and displaying the importance and utility of each option lucidly. The goal of this phase is to identify the relative importance of the factors in assessing the healthcare organization's readiness to adopt blockchain for the management of the EHR systems. The expert will as well quantify the desirability curves.

For the quantification phase, 38 experts have participated and were distributed across 6 panels as shown below. Appendix C shows the perspectives and factors quantification survey using Qualtrics software as well as the model structure in the HDM software in Appendix D. The data was collected using Qualtrics software then manually entered to the HDM software for analysis. The following two tables show the different expert panels' roles and a list of the experts participated in this phase.

Table 43. The expert panels' roles in the quantification phase

Panel #	Role	Tool	Size
P7	Quantify the perspectives	Qualtrics Survey + ETM HDM software	9
P8 F	Quantify the factors under the financial perspective	Qualtrics Survey + ETM HDM software	8
P9 S	Quantify the factors under the social perspective	Qualtrics Survey + ETM HDM software	10
P10 T	Quantify the factors under the technical perspective	Qualtrics Survey + ETM HDM software	11
P11 O	Quantify the factors under the organizational perspective	Qualtrics Survey + ETM HDM software	9
P12 L	Quantify the factors under the regulations & legal perspective	Qualtrics Survey + ETM HDM software	7

The following table shows the list of experts and their distribution across the quantification phase.

Table 44. Experts distribution across the validation panels

Expert	Title	P7	P8 F	P9 S	P10 T	P11 O	P12 L
Expert 31	Blockchain Research Scientist and Technical Representative			Y			
Expert 32	Emerging Technology Consultant and Managing Director		Y	Y			
Expert 33	Director, Health Information Exchange, and Advisor						Y
Expert 34	Presales Architect & Go-to-Market Strategy				Y	Y	

Expert 35	Computer Science Engineer				Y	Y	
Expert 36	Growth, Partnerships, New Ventures, and Business Transformation Catalyst			Y			
Expert 37	BSS Senior Consultant				Y		
Expert 38	Blockchain in bioinformatics expert & Business Intelligence Analyst	Y					
Expert 39	CEO and Affiliate Relations Manager				Y		
Expert 40	Technology Marketing Specialist	Y	Y				
Expert 41	CTO and Director of Consulting & Tech Chair		Y	Y			
Expert 42	Health Hospitality and Blockchain Analyst					Y	
Expert 43	Professor	Y					
Expert 44	President	Y					
Expert 45	CEO, Technical Director, and Blockchain Consultant and Experts					Y	
Expert 46	Manager				Y		
Expert 47	Junior Software Engineer & Blockchain Developer				Y	Y	
Expert 48	CEO and Clinical Research Scientist	Y					
Expert 49	CTO & Senior advisor	Y	Y				
Expert 50	Cognitive Solutions E&U industry leader			Y			Y
Expert 51	Blockchain and Innovation Consultant & Head Of Digital Marketing and Community	Y	Y				
Expert 52	DLT & Blockchain Consultant				Y	Y	
Expert 53	Blockchain investment expert	Y					
Expert 54	Director and DLT/Blockchain Subject Matter expert				Y	Y	
Expert 55	Blockchain IOT Entrepreneur and Angel Investor	Y					
Expert 56	Senior Blockchain Architect				Y	Y	
Expert 57	Managing Director		Y				
Expert 58	Senior Litigation Attorney						Y
Expert 59	Attorney at Law & Operations Associate						Y
Expert 60	Director					Y	
Expert 61	PhD Researcher			Y			Y
Expert 62	CEO & Digital Transformation Leader		Y	Y			
Expert 63	Software Engineer (Blockchain Engineer)			Y			Y
Expert 64	Blockchain Research Analyst		Y	Y			
Expert 65	Blockchain Technical Leader						Y
Expert 66	CTO and Advisor				Y		
Expert 67	Technology and Blockchain Consultant & Project Manager				Y		
Expert 68	Business Consultant & Enterprise Blockchain Analyst			Y			
	Number of experts per panel	**9**	**8**	**10**	**11**	**9**	**7**

The following section shows the results of the quantification phase.

Quantification Results

Perspectives Quantification

Panel 7: This panel consisted of 9 experts. The experts conducted pairwise comparisons at the top level, where they compared the perspectives against each other to determine their relative importance to the overall goal. The perspectives are financial, social, technical, organization, and regulations & legal. The total number of pairwise comparisons an expert was expected to conduct is 10. The following tables and figure show the results of the perspective's level quantification.

Table 45. The result of the perspectives level quantification by P7 expert panel

Panel 7	Financial	Social	Technical	Organizational	Regulations & Legal	Inconsistency
Expert 55	0.17	0.06	0.35	0.11	0.31	0.06
Expert 49	0.22	0.05	0.36	0.13	0.24	0.01
Expert 43	0.24	0.11	0.28	0.11	0.26	0.01
Expert 38	0.03	0.15	0.05	0.17	0.59	0.04
Expert 53	0.21	0.19	0.16	0.2	0.24	0.05
Expert 51	0.21	0.08	0.23	0.13	0.35	0.02
Expert 48	0.19	0.07	0.28	0.18	0.28	0
Expert 40	0.31	0.2	0.28	0.15	0.07	0.06
Expert 44	0.17	0.13	0.21	0.21	0.27	0.01
Mean	**0.19**	**0.12**	**0.24**	**0.15**	**0.29**	
Minimum	**0.03**	**0.05**	**0.05**	**0.11**	**0.07**	
Maximum	**0.31**	**0.2**	**0.36**	**0.21**	**0.59**	
Std. Deviation	**0.07**	**0.05**	**0.09**	**0.04**	**0.13**	
Disagreement						**0.068**

Table 46. The perspectives rankings

Perspective	Weight
Financial Perspective	0.194
Social Perspective	0.116
Technical Perspective	0.244
Organizational Perspective	0.145
Regulations & legal Perspective	0.29

Figure 29. The results of the perspectives quantification by P7 panel

The perspective's level quantification results show that the regulations & legal perspective is the most important perspective in assessing the healthcare organization's readiness for blockchain adoption. The analysis of the inconsistencies in the expert judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.068 < 0.10).

Factors under each Perspective quantification:

Financial Perspective Quantification

Panel 8 F: This panel consisted of 8 experts. The experts conducted pairwise comparisons of the financial perspective where they compared the financial factors against each other to determine their relative importance to their parent perspective and the overall goal. The financial perspective consists of three factors: Budget Availability, Financial Risk & Uncertainty and Cost Saving. The total number of pairwise comparisons an expert was expected to conduct is 3. The following tables and figure show the results of the financial perspective quantification.

Table 47. The result of the financial perspective quantification by P8 F expert panel

Financial	Budget Availability	Financial Risk and Uncertainty	Cost Saving	Inconsistency
Expert 49	0.29	0.43	0.29	0
Expert 32	0.41	0.41	0.18	0
Expert 41	0.56	0.14	0.31	0
Expert 62	0.38	0.38	0.25	0
Expert 57	0.33	0.43	0.25	0
Expert 51	0.29	0.43	0.29	0
Expert 40	0.28	0.26	0.46	0.07
Expert 64	0.37	0.42	0.21	0.01
Mean	**0.36**	**0.36**	**0.28**	
Minimum	**0.28**	**0.14**	**0.18**	
Maximum	**0.56**	**0.43**	**0.46**	
Std. Deviation	**0.09**	**0.1**	**0.08**	
Disagreement				**0.076**

Table 48 . The financial factors rankings

Financial factors	Weight
Budget Availability	36.38%
Financial Risk & Uncertainty	36.25%
Cost Saving	28%

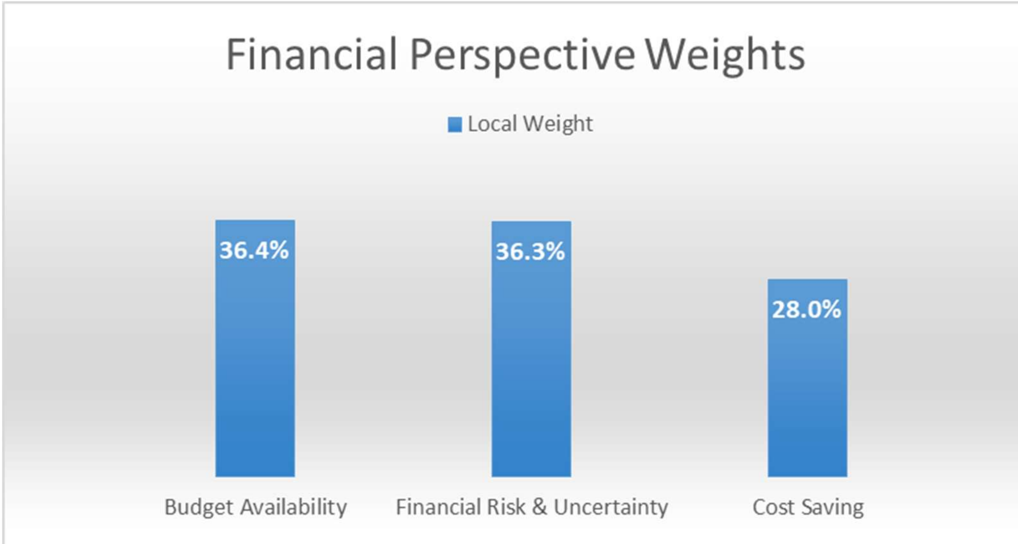

Figure 30. The results of the financial factors quantification by P8 F panel

The financial factors quantification results show that Budget Availability and Financial Risk & Uncertainty factors are tied for the most important factor in the financial perspective. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.076 < 0.10). The inconsistency and disagreement levels are at the acceptable levels.

Social Perspective Quantification

Panel 9 S: this panel consisted of 10 experts. The experts conducted pairwise comparisons of the social perspective where they compared the social factors against each other to determine their relative importance to their parent perspective and the overall goal. The social perspective consists of four factors: Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and

Disintermediation & Business Process. The total number of pairwise comparisons an expert was expected to conduct is 6. The following tables and figure show the results of the social perspective quantification.

Table 49. The result of the social perspective quantification by P9 S expert panel

Social	Talent & Knowledge Acquisition	Stakeholder's Awareness & Acceptance	Blockchain Ecosystem	Disintermediation & Business Process	Inconsistency
Expert 31	0.16	0.24	0.24	0.36	0.03
Expert 68	0.16	0.19	0.25	0.4	0
Expert 32	0.63	0.12	0.19	0.06	0.03
Expert 41	0.29	0.31	0.18	0.22	0.07
Expert 62	0.3	0.27	0.2	0.22	0
Expert 36	0.23	0.3	0.14	0.33	0.02
Expert 61	0.28	0.24	0.34	0.14	0.02
Expert 63	0.32	0.21	0.32	0.14	0
Expert 64	0.25	0.34	0.22	0.2	0.01
Expert 50	0.4	0.17	0.2	0.23	0.05
Mean	**0.3**	**0.24**	**0.23**	**0.23**	
Minimum	**0.16**	**0.12**	**0.14**	**0.06**	
Maximum	**0.63**	**0.34**	**0.34**	**0.4**	
Std. Deviation	**0.13**	**0.06**	**0.06**	**0.1**	
Disagreement					**0.081**

Table 50. The social factors rankings

Social factors	Weight
Talent & Knowledge acquisition	30.2%
Stakeholder's Awareness & Acceptance	23.9%
Blockchain Ecosystem	22.8%
Disintermediation & Business Process	23.0%

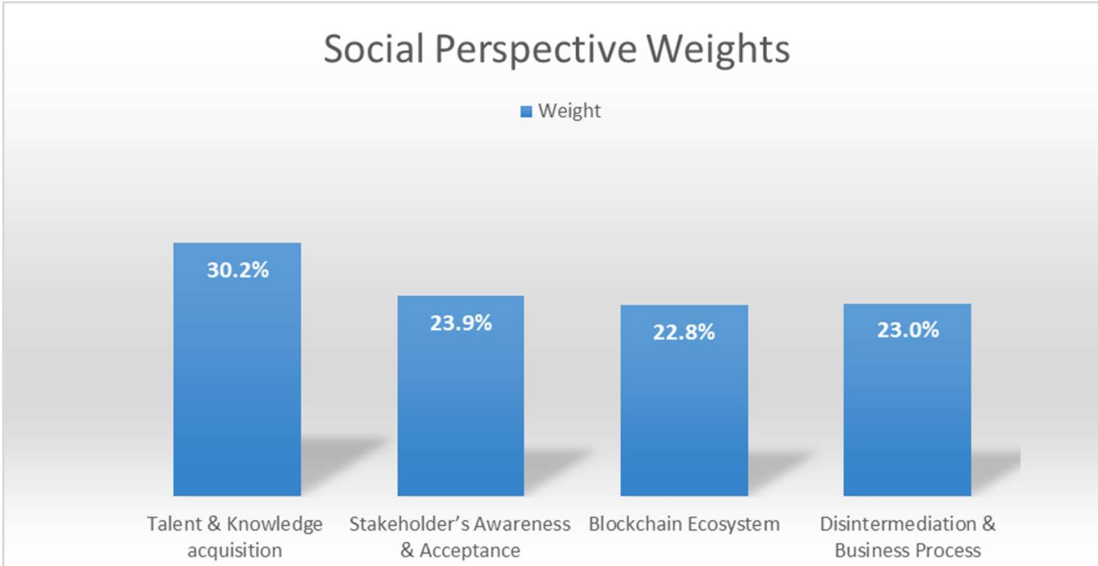

Figure 31. The results of the social factors quantification by P9 S panel

The social factors quantification results show that the Talent & Knowledge acquisition factor is the most important factor in the social perspective. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.081 < 0.10). The inconsistency and disagreement levels are at the acceptable levels.

Technical Perspective Quantification

Panel 10 T: this panel consisted of 11 experts. The experts conducted pairwise comparisons of the technical perspective where they compared the technical factors against each other to determine their relative importance to their parent perspective and the overall goal. The technical perspective consists of four factors: Infrastructure Availability & compatibility, Standardization, Security and Privacy, and Blockchain Maturity & Use Cases. The total number of pairwise comparisons an expert was expected to conduct is 6. The following tables and figure show the results of the technical perspective quantification.

Table 51. The result of the technical perspective quantification by P10 T expert panel

Technical	Infrastructure & Platform Integration	Standardization	Security and privacy	Blockchain Maturity & Use Cases	Inconsistency
Expert 47	0.2	0.22	0.27	0.3	0.01
Expert 35	0.2	0.28	0.36	0.16	0.01
Expert 54	0.24	0.36	0.24	0.16	0.03
Expert 46	0.16	0.27	0.33	0.24	0
Expert 39	0.29	0.19	0.33	0.19	0.01
Expert 37	0.14	0.29	0.38	0.2	0
Expert 56	0.24	0.29	0.32	0.14	0.02
Expert 34	0.36	0.19	0.27	0.18	0.01
Expert 66	0.06	0.19	0.67	0.08	0
Expert 67	0.31	0.07	0.3	0.32	0.09
Expert 52	0.14	0.14	0.35	0.37	0
Mean	**0.21**	**0.23**	**0.35**	**0.21**	
Minimum	**0.06**	**0.07**	**0.24**	**0.08**	
Maximum	**0.36**	**0.36**	**0.67**	**0.37**	
Std. Deviation	**0.08**	**0.08**	**0.11**	**0.08**	
Disagreement					**0.078**

Table 52. The technical factors rankings

Technical factors	Weight
Infrastructure & Platform Integration	21.3%
Standardization	22.6%
Security and Privacy	34.7%
Blockchain Maturity & Use Cases	21.3%

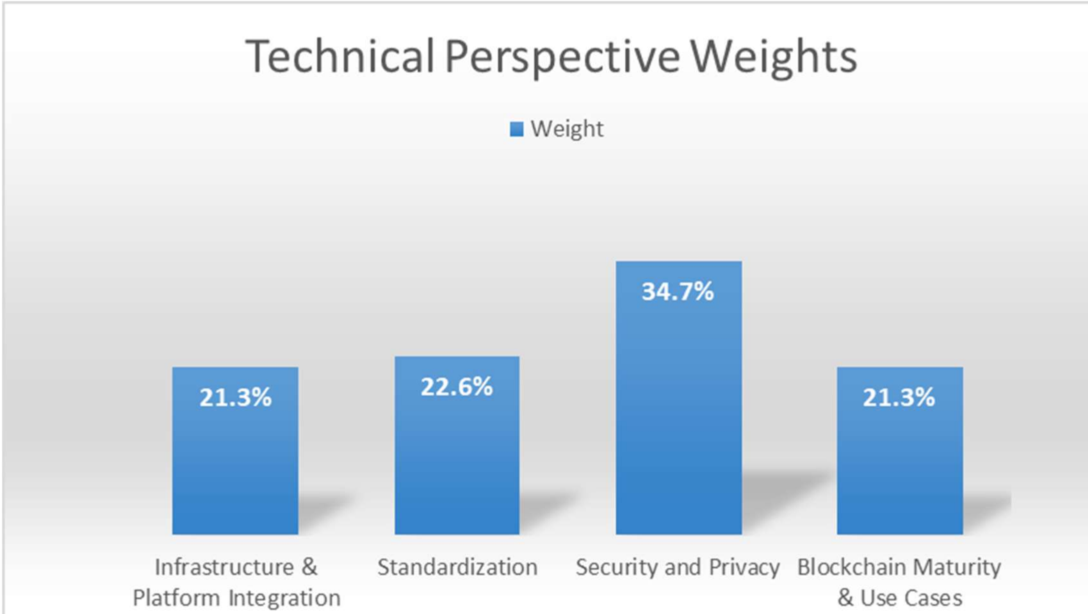

Figure 32 . The results of the technical factors quantification by P10 T panel

The technical factors quantification results show that the Security and Privacy factor is the most important factor in the technical perspective. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.078 < 0.10). The inconsistency and disagreement levels are at the acceptable levels.

Organizational Perspective Quantification

Panel 11 O: this panel consisted of 9 experts. The experts conducted pairwise comparisons of the organizational perspective where they compared the organizational factors against each other to determine their relative importance to their parent perspective and the overall goal. The organizational perspective consists of three factors: Management Support, Training and Skills, and HIT Strategy. The total number of pairwise comparisons an expert was expected to conduct is 6. The following tables and figure show the results of the organizational perspective quantification.

Table 53. The result of the organizational perspective quantification by P11 O expert panel

Organizational	Management Support	Training & Skills	HIT strategy	Inconsistency
Expert 47	0.38	0.29	0.33	0
Expert 35	0.29	0.29	0.43	0
Expert 54	0.47	0.18	0.36	0
Expert 45	0.38	0.16	0.46	0.02
Expert 60	0.72	0.07	0.22	0.01
Expert 56	0.53	0.14	0.34	0
Expert 34	0.44	0.18	0.38	0
Expert 42	0.37	0.21	0.42	0.02
Expert 52	0.33	0.38	0.29	0
Mean	**0.43**	**0.21**	**0.36**	
Minimum	**0.29**	**0.07**	**0.22**	
Maximum	**0.72**	**0.38**	**0.46**	
Std. Deviation	**0.12**	**0.09**	**0.07**	
Disagreement				**0.081**

Table 54. The organizational factors rankings

Organizational factors	Weight
Management Support	43.4%
Training and Skills	21.1%
HIT Strategy	35.9%

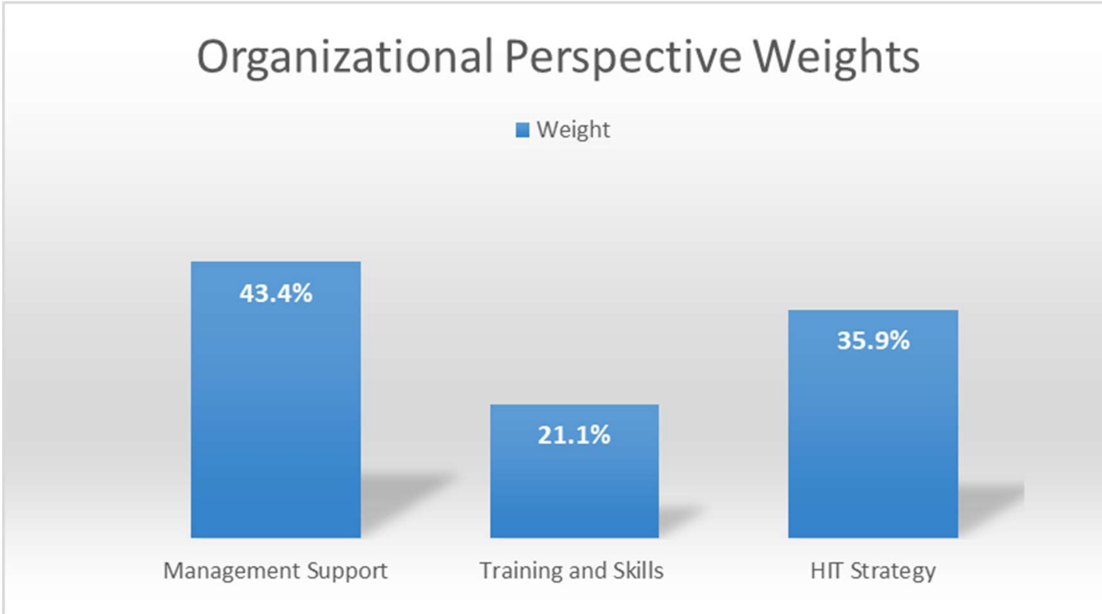

Figure 33 . The results of the organizational factors quantification by P11 O panel

The organizational factors quantification results show that the Management Support factor is the most important factor in the organizational perspective. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.081 < 0.10). The inconsistency and disagreement levels are at the acceptable levels.

Regulations & Legal Perspective Quantification:

Panel 12 L: this panel consisted of 7 experts. The experts conducted pairwise comparisons of the regulations & legal perspective where they compared the regulations & legal factors against each other to determine their relative importance to their parent perspective and the overall goal. The regulations & legal perspective consists of three factors: Regulation Compliance, Incentives Availability, and Regulatory Uncertainty &

Governance. The total number of pairwise comparisons an expert was expected to conduct is 3. The following tables and figure show the results of the regulations & legal perspective quantification.

Table 55. The result of the regulations & legal perspective quantification by P12 L expert

Regulations & Legal	Regulation Compliance	Regulatory Uncertainty & Governance	Incentives Availability	Inconsistency
Expert 65	0.38	0.27	0.34	0
Expert 61	0.37	0.21	0.42	0.01
Expert 33	0.24	0.57	0.19	0
Expert 58	0.43	0.14	0.43	0
Expert 63	0.31	0.48	0.21	0
Expert 59	0.36	0.35	0.29	0.05
Expert 50	0.52	0.32	0.16	0.01
Mean	**0.37**	**0.33**	**0.29**	
Minimum	**0.24**	**0.14**	**0.16**	
Maximum	**0.52**	**0.57**	**0.43**	
Std. Deviation	**0.08**	**0.14**	**0.1**	
Disagreement				**0.098**

Table 56. The regulations & legal factors rankings

Regulations & Legal factors	Weight
Regulation Compliance	37.3%
Regulatory Uncertainty & Governance	33.4%
Incentives Availability	29.1%

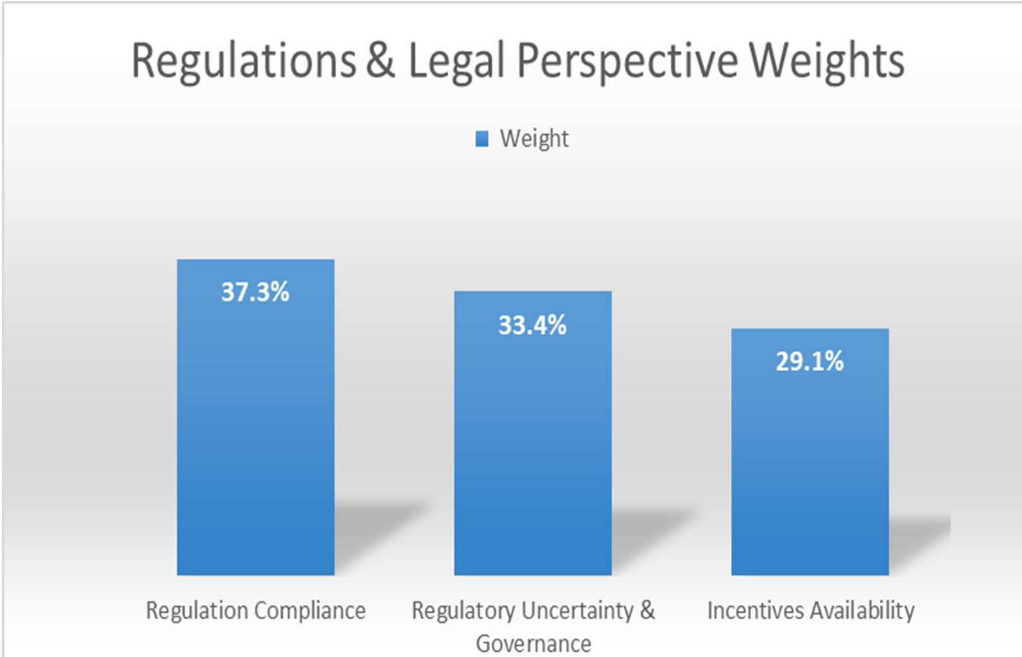

Figure 34. The results of the regulations & legal factors quantification by P12 L panel

The regulations & legal factors quantification results show that the Regulation Compliance factor is the most important factor in the regulations & legal perspective. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments since their inconsistency levels were below the threshold of 0.10. Also, the disagreement level among the experts is below the threshold of 0.10 (0.098 < 0.10). The inconsistency and disagreement levels are at the acceptable levels.

To further understand the disagreement level in this expert panel, a cluster analysis has been performed to identify the subgroups and better understand the sources of the disagreement. Usually, such analysis is performed when the disagreement exceeds the threshold of 0.10.

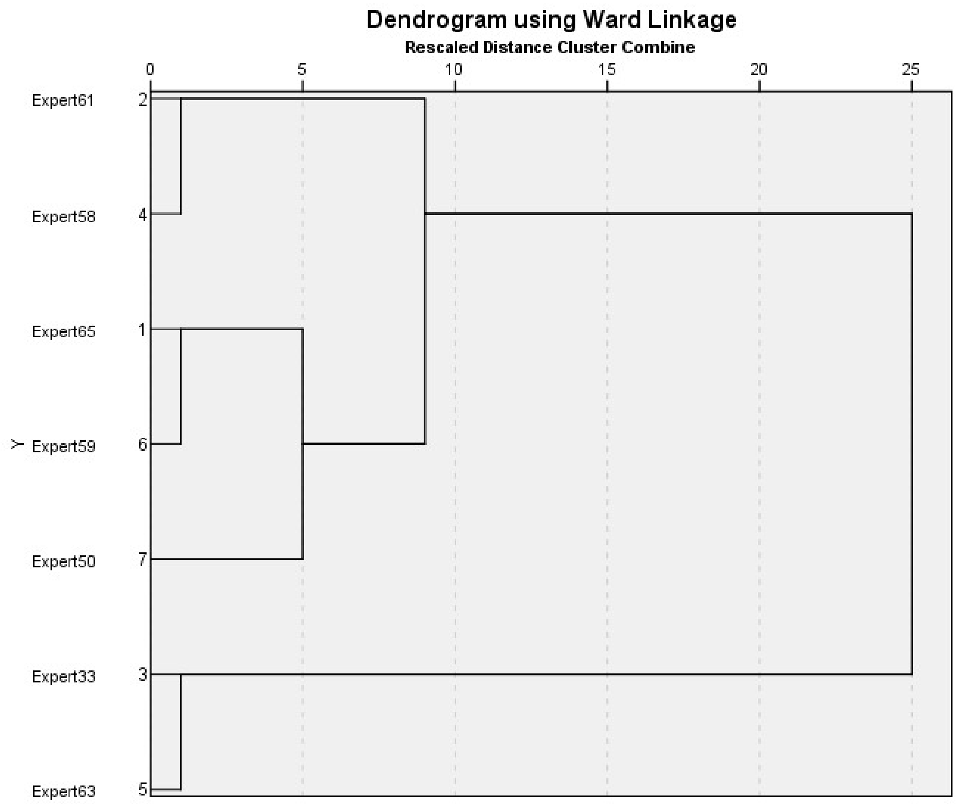

Figure 35. Subgroups in expert panel P12 L using dendrogram

Subgroup analysis has identified 2 subgroups within expert panel 12 L. Please see the figure above for details. Group disagreement indices for each subgroup; subgroup A (0.072) and subgroup B (0.033) are lower than the threshold of 0.10. Experts ‘individual relative priorities, inconsistency levels, aggregated group results, and group disagreement indices for each subgroup are shown in the tables below.

Subgroup “A” is the largest group in expert panel 12 L and consists of 5 experts (Expert 65, Expert 61, Expert 58, Expert 59, and Expert 50).

Subgroup “A” disagreement analysis results of P12 L Panel is shown below

Table 57. Analysis of Subgroup "A" results of P12 L panel

Regulations & Legal	Regulation Compliance	Regulatory Uncertainty & Governance	Incentives Availability	Inconsistency
Expert 65	0.38	0.27	0.34	0
Expert 61	0.37	0.21	0.42	0.01
Expert 58	0.43	0.14	0.43	0
Expert 59	0.36	0.35	0.29	0.05
Expert 50	0.52	0.32	0.16	0.01
Mean	**0.41**	**0.26**	**0.33**	
Minimum	**0.36**	**0.14**	**0.16**	
Maximum	**0.52**	**0.35**	**0.43**	
Std. Deviation	**0.06**	**0.08**	**0.1**	
Disagreement				**0.072**

Subgroup "B" is the smaller group in expert panel 12 L and consists of 2 experts (Expert 33 and Expert 63).

Table 58. Analysis of Subgroup "B" results of P12 L panel

Regulations & Legal	Regulation Compliance	Regulatory Uncertainty & Governance	Incentives Availability	Inconsistency
Expert 33	0.24	0.57	0.19	0
Expert 63	0.31	0.48	0.21	0
Mean	**0.28**	**0.53**	**0.2**	
Minimum	**0.24**	**0.48**	**0.19**	
Maximum	**0.31**	**0.57**	**0.21**	
Std. Deviation	**0.03**	**0.05**	**0.01**	
Disagreement				**0.033**

Model Weights

The previous section showed the quantification results for the perspectives and factors contributions to their parents' perspectives. This section will show the global contribution of the factors to the overall objective of assessing the healthcare organization's readiness for the blockchain adoption. The regulations & legal perspective is the most important perspective. The most important factors to the overall objective of assessing the healthcare organization's readiness for the blockchain adoption are the Financial Risk & Uncertainty factor (11.4%), followed by Incentives Availability factor (9.0%), and then Cost saving factor (8.9%).

Table 59. The Overall Model Weights

Perspective		Factor	Local Weight	Global Weight
Financial Perspective	**0.194**	Budget Availability	36.4%	**7.1%**
		Financial Risk & Uncertainty	36.3%	**7.0%**
		Cost Saving	28.0%	**5.4%**
Social Perspective	**0.116**	Talent & Knowledge acquisition	30.2%	**3.5%**
		Stakeholder's Awareness & Acceptance	23.9%	**2.8%**
		Blockchain Ecosystem	22.8%	**2.6%**
		Disintermediation & Business Process	23.0%	**2.7%**
Technical Perspective	**0.244**	Infrastructure & Platform Integration	21.3%	**5.2%**
		Standardization	22.6%	**5.5%**
		Security and Privacy	34.7%	**8.5%**
		Blockchain Maturity & Use Cases	21.3%	**5.2%**
Organizational Perspective	**0.154**	Management Support	43.4%	**6.7%**
		Training and Skills	21.1%	**3.3%**
		HIT Strategy	35.9%	**5.5%**
Regulations & legal Perspective	**0.290**	Regulation Compliance	37.3%	**10.8%**
		Regulatory Uncertainty & Governance	33.4%	**9.7%**
		Incentives Availability	29.1%	**8.5%**
Total	1.00			**100%**

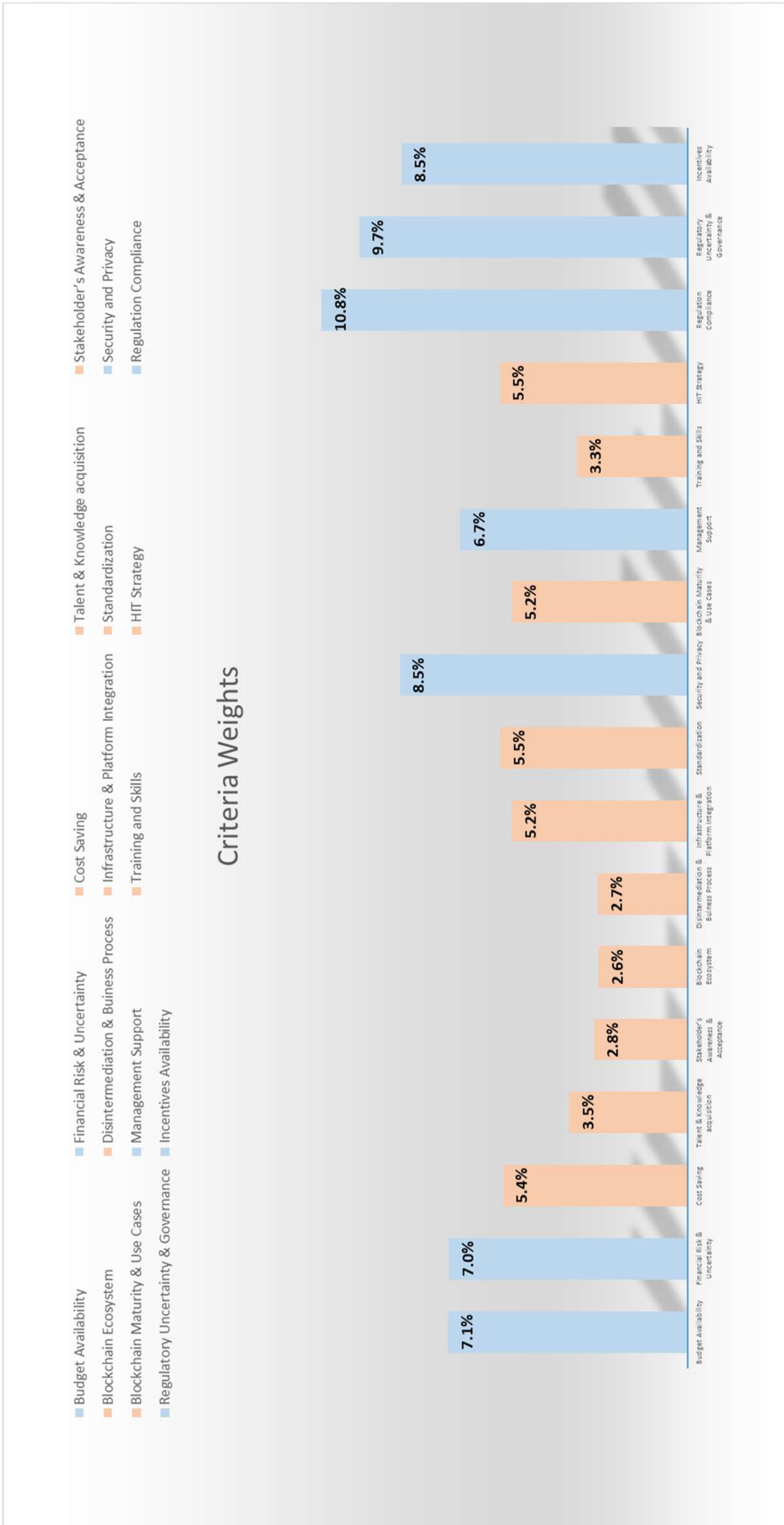

Figure 36. Factors Global Weights

Results Analysis

The Inconsistency and Disagreement Levels Analysis

This research employs expert judgments inconsistency and disagreement analysis. Expert's judgments data were examined for inconsistency using the average standard deviation method that was calculated by the HDM software. The analysis of the inconsistencies in the experts' judgments shows that all the experts showed consistency in their judgments across all the experts in all of the expert panels since their inconsistency levels were below the threshold of 0.10. Also, the disagreement levels among the experts in each expert panel was examined. The disagreement levels among the experts were all below the threshold of 0.10 across all expert panels. One expert panel has a disagreement level pretty close to the threshold and a subgroup analysis was undertaken to further understand the source of disagreement and if it is justified and tolerable. The analysis explained why the level was high and was accepted. The inconsistency and disagreement levels are at the acceptable levels.

Final Model Ranking

After finalizing the model based on the validation of the factors extracted from the literature review, the experts quantified these factors to identify their relative importance to the overall objective of assessing the healthcare organization's readiness to adopt blockchain for the management of the EHR systems. The following figure 73 shows a depiction of the model with the factor's weights.

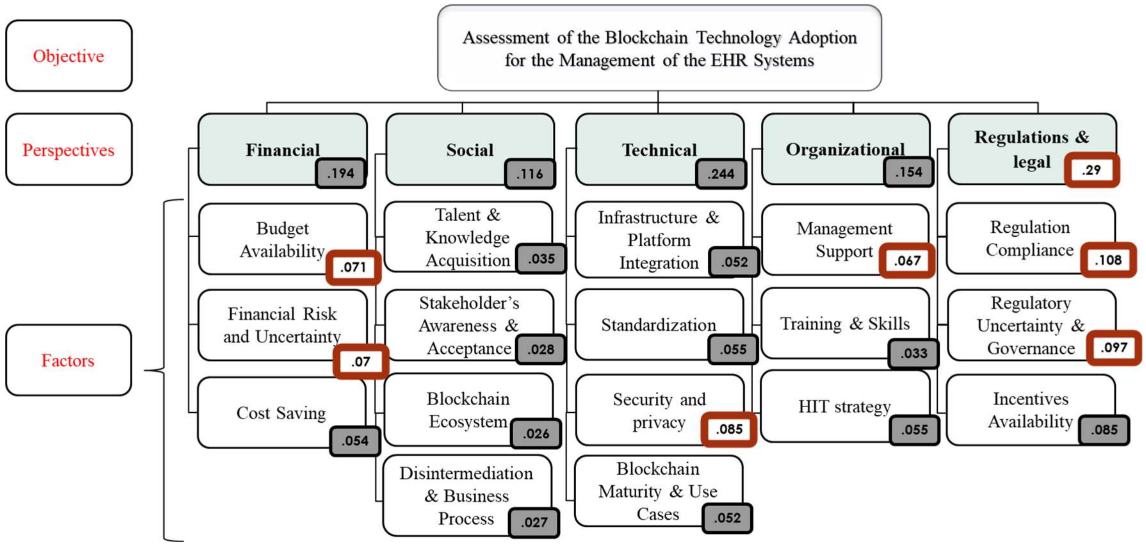

Figure 37. HDM with factor's weights

6.3.3 The Desirability Metrics

The desirability curves represent metrics/levels that could be assigned to a healthcare organization's status/performance against each factor in the model. It is used to identify how desirable or valuable a metric is for a decision-maker. The unit of measurements for each factor has been captured using a scale from 0 to 100. The experts assigned a score from 0 to 100 for each level within every factor expressing how desirable that specific level. The following section will show the results of desirability curves quantifications. In order to do validate and quantify the desirability curves, inputs from experts throughout the validation and quantification phases have been used to develop the desirability levels. Then, they were presented and discussed in an interview with health IT professional who is involved at the development and implementation of the health IT solutions at his healthcare organization as well as another executive with academic and health IT experience at another health institution for finalization and approval. The following present the desirability levels and curves developed to measure each of the model constructs.

Financial perspective:

Budget Availability:

- No budget is allocated.
- Limited budget
- Medium fund is allocated for only the execution of the project
- Healthcare organization is realizing the importance and relevance of the project and committed to providing the needed financial resources for the execution and long-term support commitment.

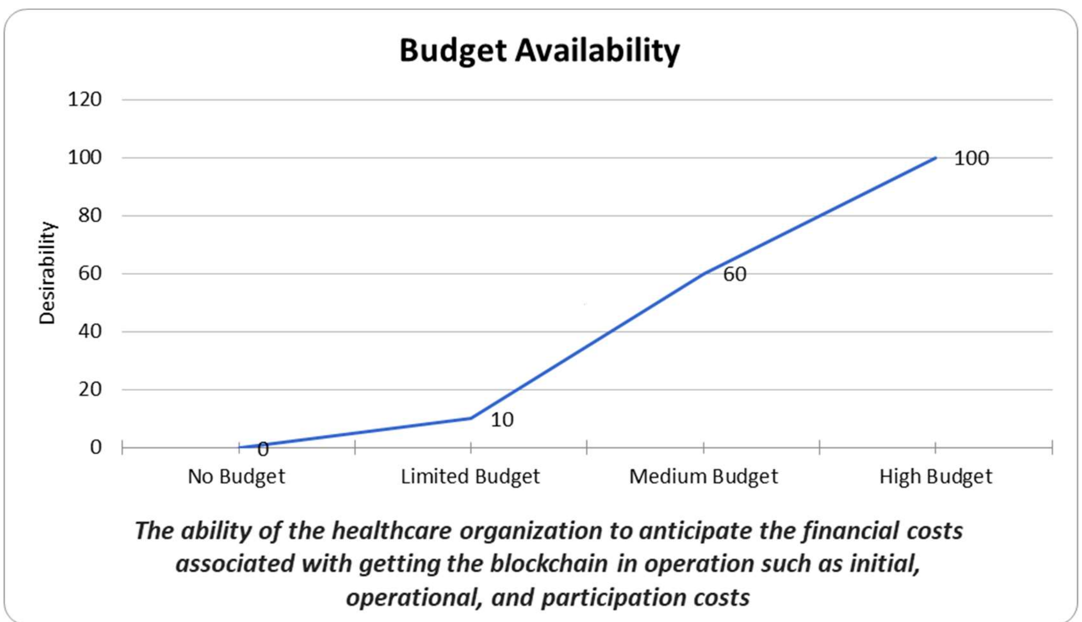

Figure 38. Budget availability curve

Financial Risk & Uncertainty:

This factor measures the ability of the healthcare organization to conduct risk assessments and anticipate various financial costs associated with getting Blockchain to work, such as expanding the Blockchain network, cost of transactions, maintenance, and scalability.

- No financial measurements or risk assessments exist
- Some clarity with few measures in place
- Medium clarity with various measures in place
- High clarity and certainty of the costs and solid measures have been performed.

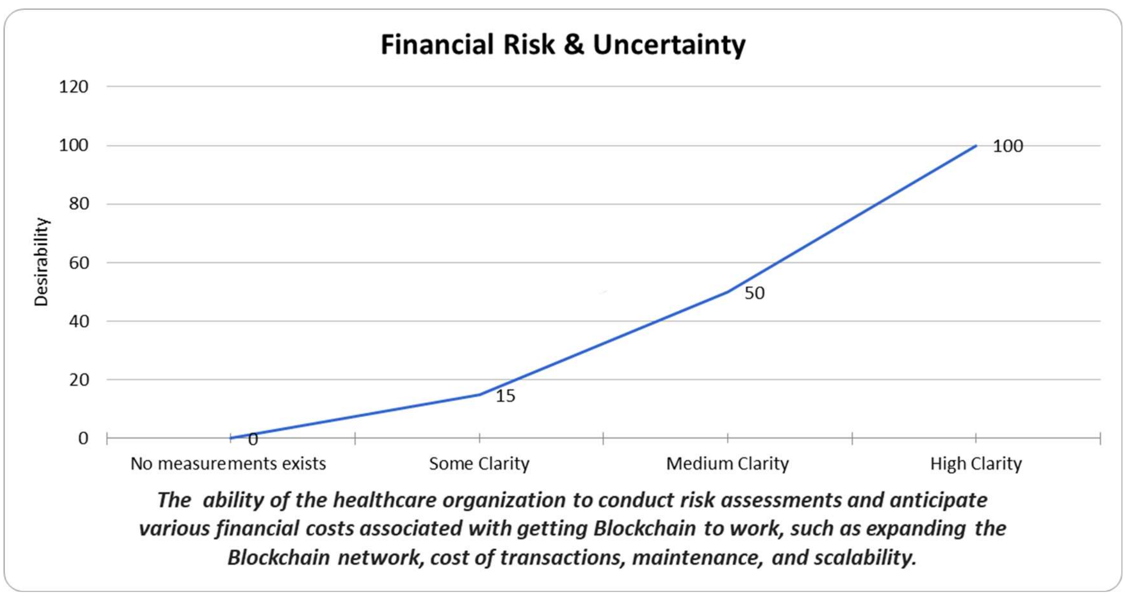

Figure 39 .Financial Risk & Uncertainty Curve

Cost Saving:

- Healthcare organization is unclear of the cost-saving blockchain generate and has no financial cost reduction goals set yet,
- Healthcare organization is, to some extent, clear of the cost reduction and has some financial cost reduction goals set.
- Healthcare organization has medium clarity of the cost reduction.
- Healthcare organization is certain of the cost-saving and measurement are in place as well as the financial goals are well defined and set.

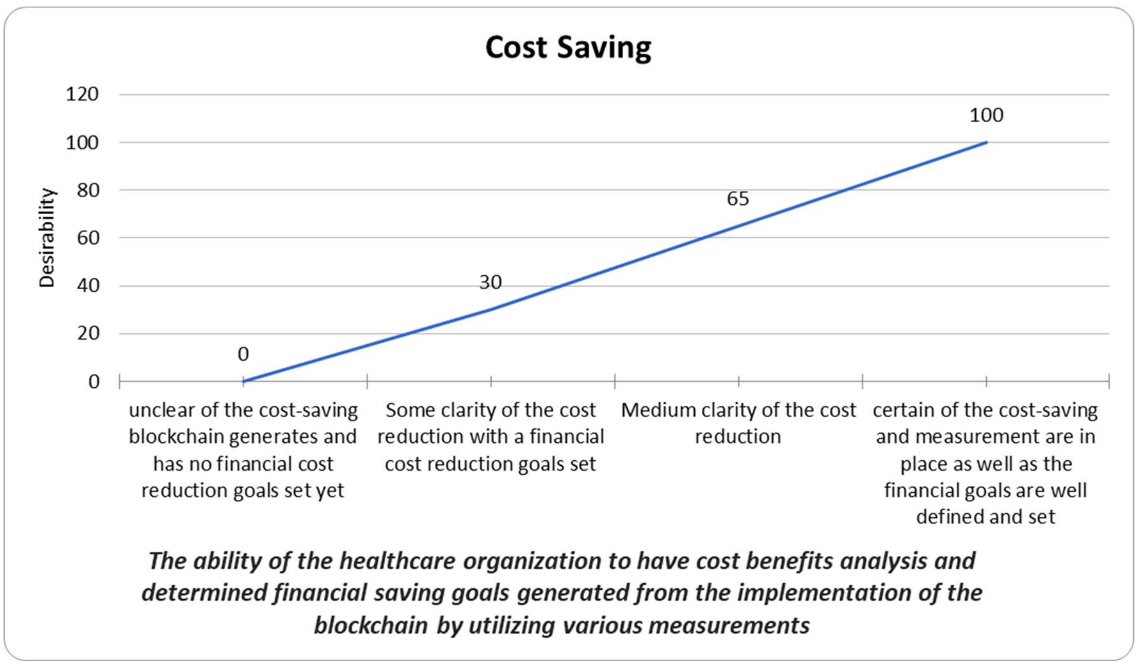

Figure 40. Cost Saving Curve

Social Perspective

Talent & Knowledge acquisition:

This factor measures the current performance of the organization in acquiring skilled and relevant talents. Below are the categories:

- No capabilities to acquire external knowledge and talents
- Low capabilities in acquiring external knowledge and talents
- Moderate capabilities in acquiring external knowledge and talents
- High capabilities in acquiring external knowledge and talents

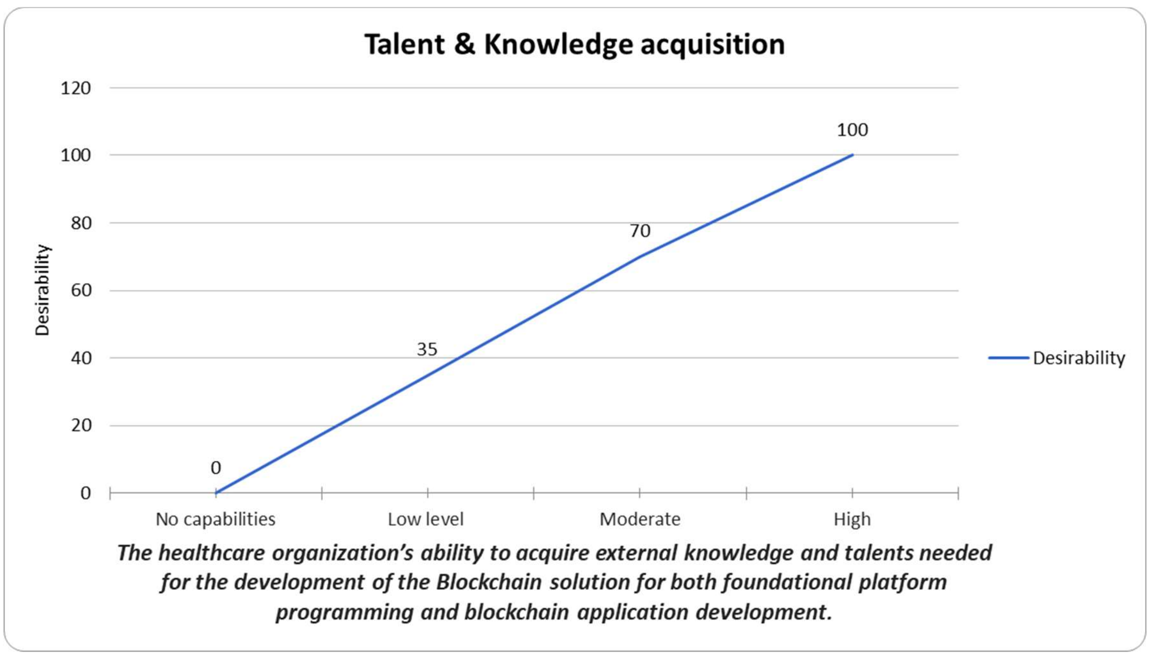

Figure 41. Talent & Knowledge acquisition

Stakeholder's Awareness & Acceptance:

This factor measures the level of stakeholder's engagement, awareness, and acceptance of the blockchain project.

- Stakeholders are not aware of the relevance, and benefits and challenges of the blockchain technology and require intensive education.
- Stakeholders have a low level of awareness and require education.
- Stakeholders have a medium level of awareness and require some education.
- Stakeholders support the initiative and realize its relevance and benefits.

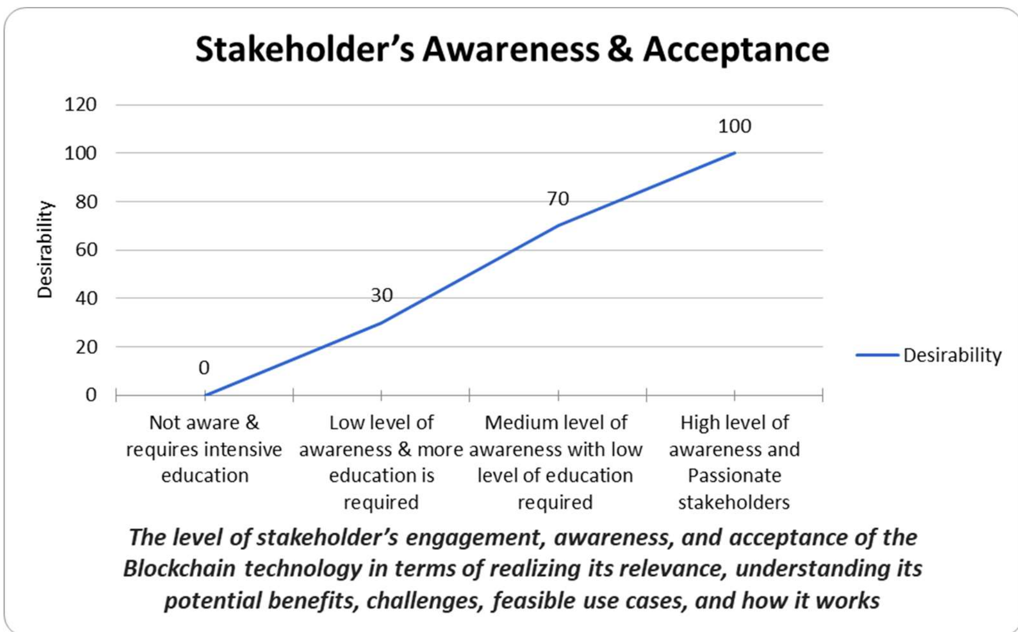

Figure 42. Stakeholder's Awareness & Acceptance

Blockchain Ecosystem:

- No interaction with blockchain ecosystem entities whatsoever
- Sparse to frequent interaction with Blockchain Ecosystem entities; no cooperation
- Medium frequency interaction
- High frequency interaction

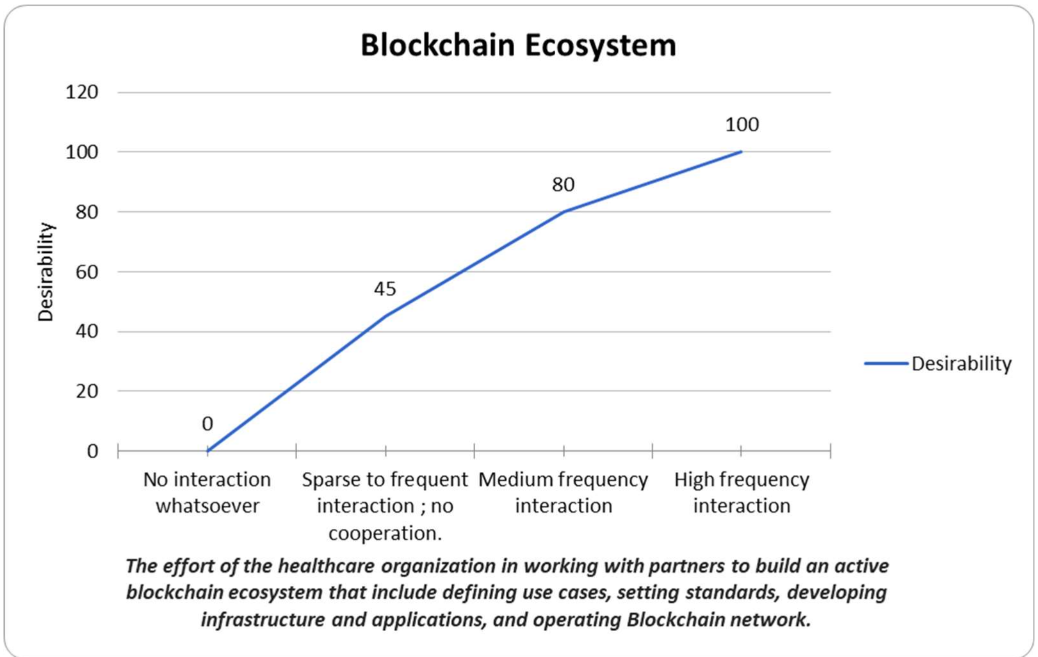

Figure 43. Blockchain Ecosystem Curve

Disintermediation & Business Process:

This factor measures the willingness of the healthcare organizations to adopt new business process by allowing an auto exchange of data through distributed ledger and eliminating nonvalue generating processes or entities.

- Not willing to allow an auto exchange of data and eliminate processes or entities
- Low willingness
- Medium willingness
- High willingness

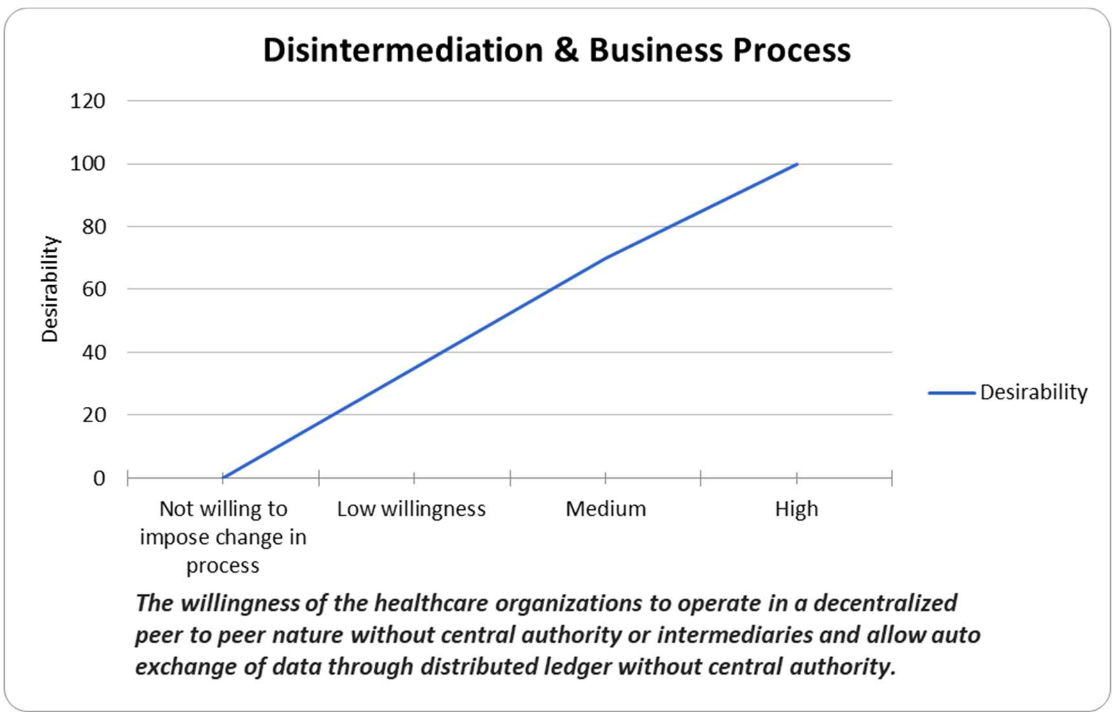

Figure 44. Disintermediation & Business Process Curve

Technical Perspective:

Infrastructure & Platform Integration:

- Very Complex, the healthcare organization requires several hardware and software infrastructure to support the blockchain implementation.
- Some Complexity, the healthcare organization requires few hardware and software infrastructure to support the implementation with few integration issues.
- Reasonable, the healthcare organization has the basic and necessary hardware and software infrastructure to support the implementation.
- Advanced, the healthcare organization has advanced hardware and software infrastructure to support the implementation with no integration issues.

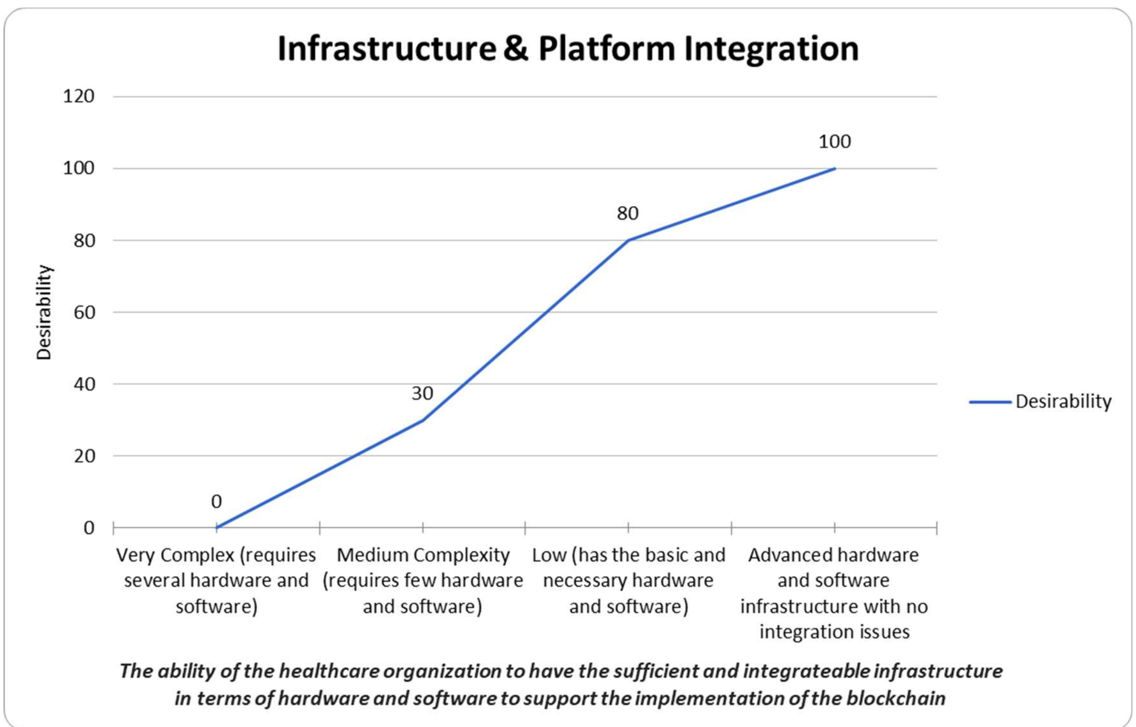

Figure 45. Infrastructure & Platform Integration Curve

Standardization:

This factor measures the ability of the healthcare organization to be clear on what data, size and format can be sent to the blockchain as well as agree on common terms, business logic and business flow as they share access to the same data and apply the same smart contract-enabled business logic.

- No standards exist
- Minimum standards exist
- Medium standards exist,
- High level of agreed-upon standardization is in place

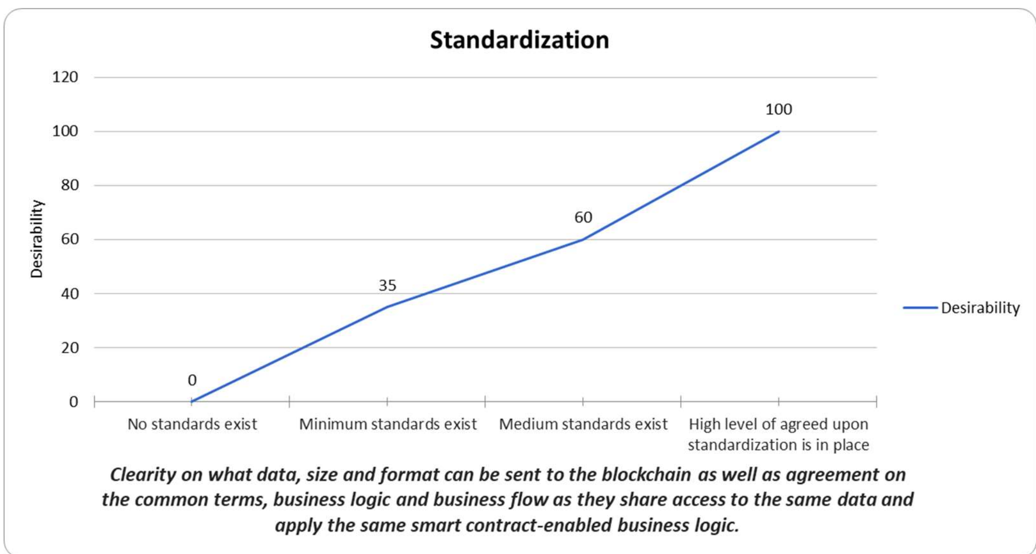

Figure 46. Standardization Curve

Security and Privacy:

This factor measures the ability of the healthcare organization to identify and foresee the areas of deficiency related to system security and technical features of the current practices and role of Blockchain in improving the security of the health records in order to prevent any malicious access to healthcare information by unauthorized entities. Below are the categories:

- Low Security and Privacy expertise
- Medium Security and Privacy expertise
- High Security and Privacy expertise
- Advanced Security and Privacy expertise

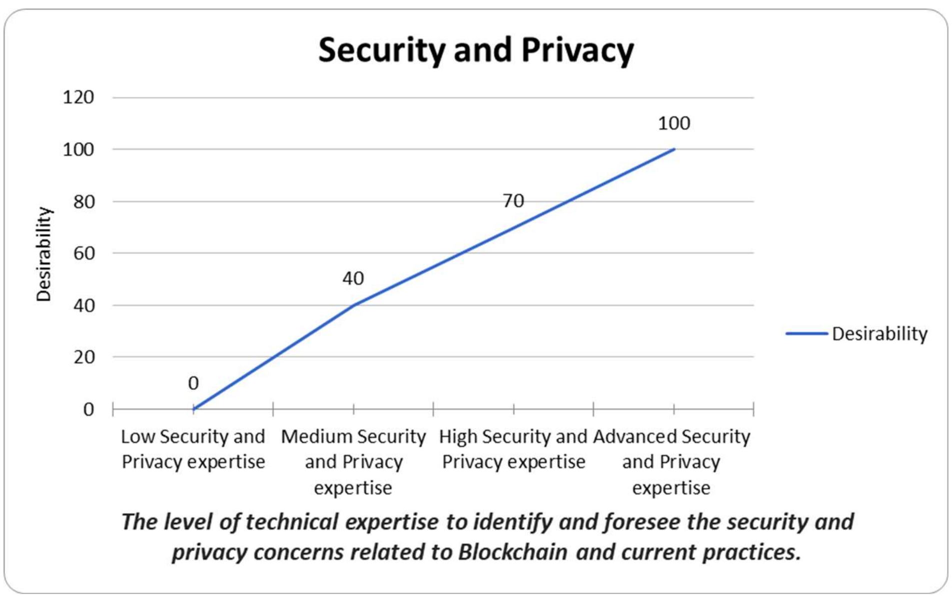

Figure 47. Security and Privacy Curve

Blockchain Maturity & Use Cases:

This factor measures the activities and efforts of the healthcare organization to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects.

- No efforts have been undertaken (No use case identified)
- Efforts have been established through learning programs and collaboration with other entities to share knowledge but not uses cases have been developed.
- Use cases have been identified but no project took place.
- Small projects with limited capabilities have been implemented and the technology has been tested with few issues.
- Advanced understanding of the technology and the healthcare organization is confident and comfortable with a large-scale project.

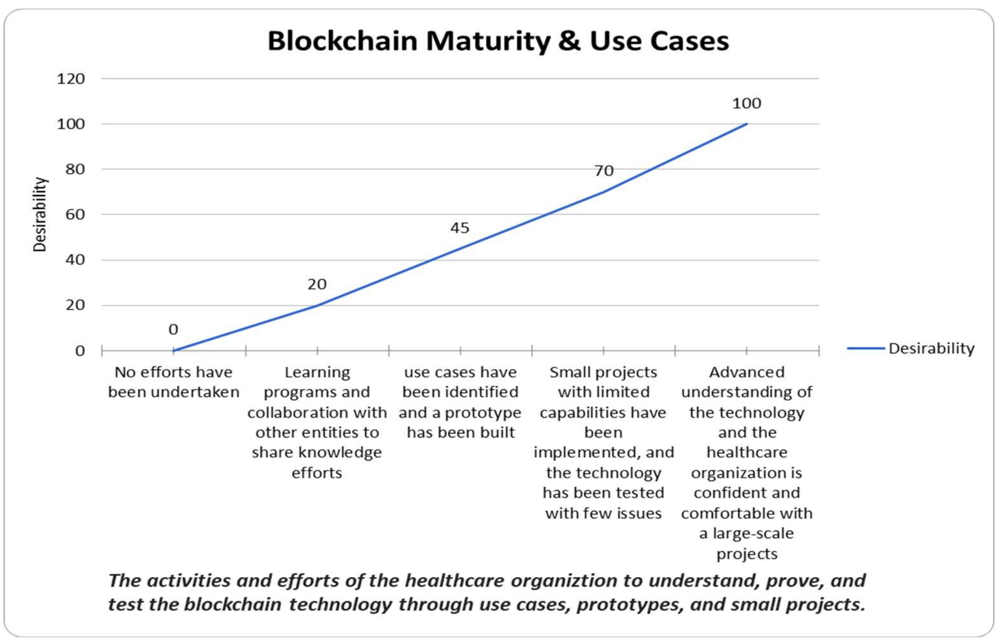

Figure 48. Blockchain Maturity & Use Cases Curve

Organizational Perspective:

Management Support:

- Opposed
- Indifferent
- Low to reluctance support
- Good to Enthusiastic Support
- Passionate (consistent engagement and support by top management)

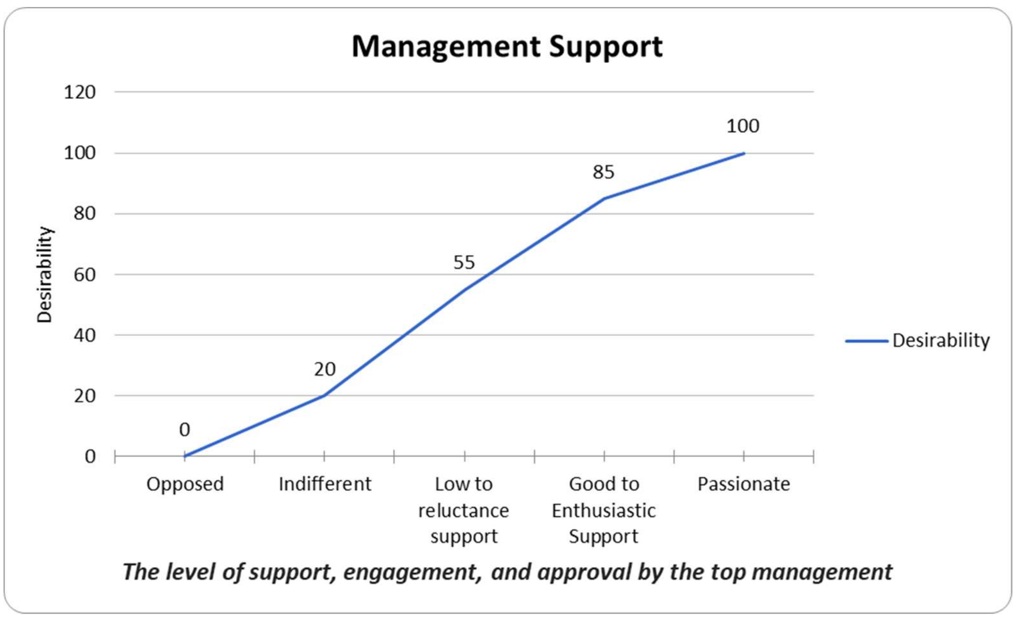

Figure 49. Management Support Curve

Training and Skills:

This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help existing technical specialists involved with the Blockchain adoption, implementation, and maintenance attain the required level of knowledge or skill related to Blockchain solution as well as expedite the learning process.

- Skillset and training needed does not exist.
- Skillset is defined to some extent and there is low frequency and informal training available
- Skillset is defined, and average frequency and formal training.
- Skillset is well defined and there is strong commitment to providing high frequency multidisciplinary formal routine training.

Figure 50. Training and Skills Curve

HIT Strategy:

This factor measures the maturity and alignment of the Blockchain solution with the healthcare organization's IT strategy and the objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem.

- No Strategy for blockchain adoption exists
- Simple Strategy
- Medium Strategy
- Advanced to Mature Strategy

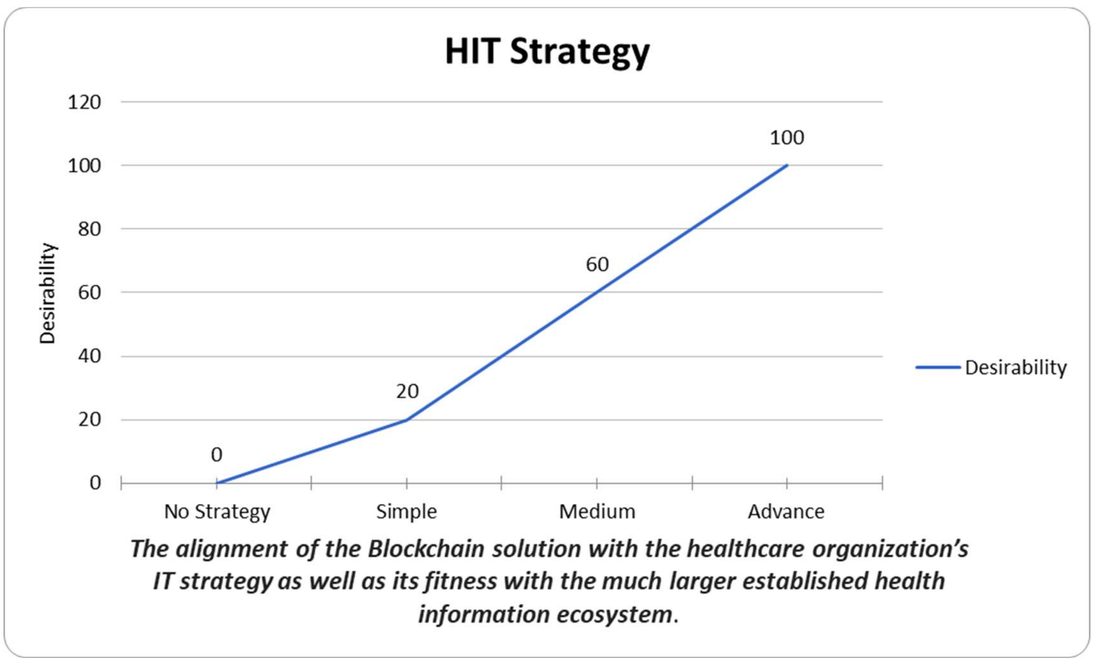

Figure 51. HIT Strategy Curve

Regulations & legal Perspective:

Regulation Compliance:

- No legal and technology transfer teams are involved in the implementation.
- low level of experience and understanding of the blockchain technology team is involved.
- Medium level of experienced team is involved.
- Dedicated experienced legal and technology transfer teams are involved with sufficient understanding of the blockchain technology to guide the effort and comply with regulations and policies.

Figure 52. Regulation Compliance Curve

Regulatory Uncertainty & Governance:

This factor measures the level of clarity on the governance strategy regarding blockchain consensus mechanism and in dealing with the regulatory landscape.

- No governance strategy exists.
- Simple (documented) governance strategy.
- Medium (documented and regularly updated) governance strategy.
- Advanced (documented, updated, and audited regularly) governance strategy.

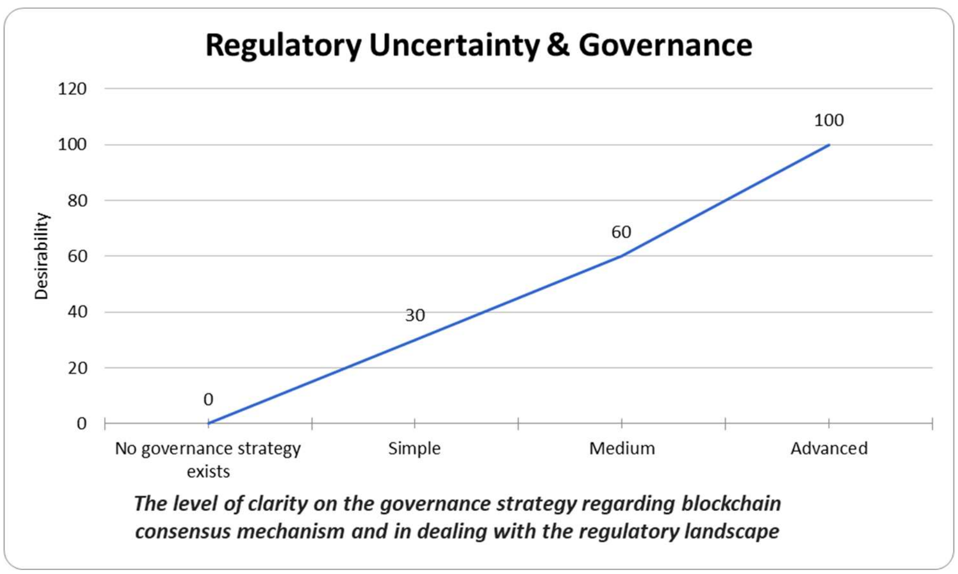

Figure 53. Regulatory Uncertainty & Governance Curve

Incentives Availability:

This factor examines the ability of the healthcare organization to work with partners and government officials as possible to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the blockchain network.

- No incentives; No collaboration exists. 0
- No incentives; Low level of collaboration. 15
- Low incentives (at partners level) with some collaboration efforts (with partners).
- Good incentives (partners and Gov) and good level of collaboration (with partners and Gov).

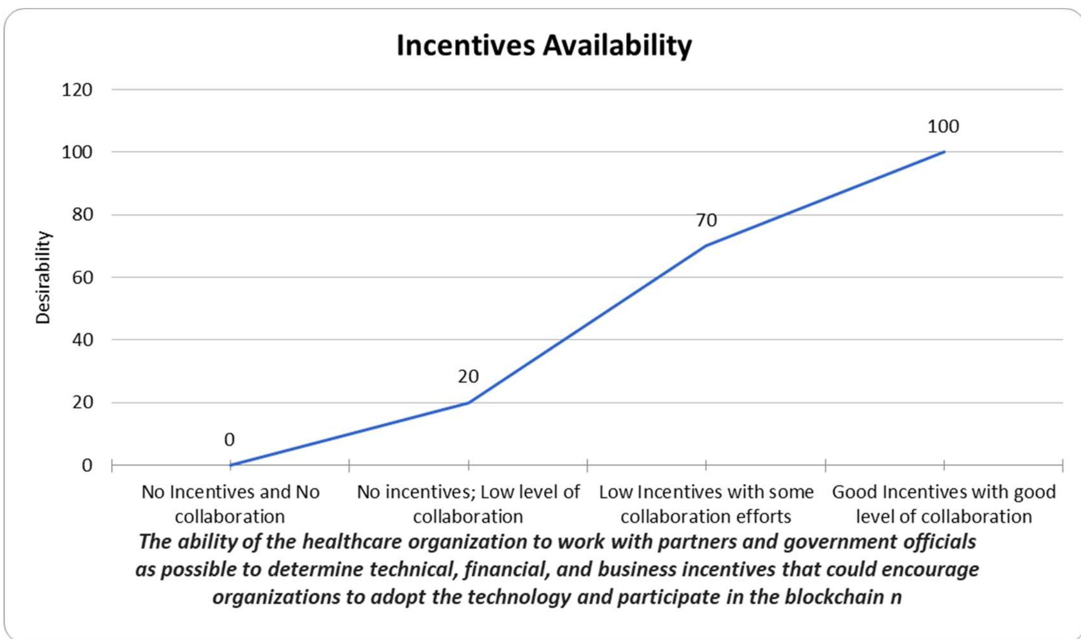

Figure 54. Incentives Availability Curve

CHAPTER 7: CASE STUDIES

The goal of this research is to identify and rank the factors that impact the blockchain adoption, assess healthcare organization's readiness to address the adoption factors and be ready for the adoption, and pinpoint areas where improvements need to be done before initiating such project. At this stage, the research model has been validated and quantified by blockchain subject matter experts and ready for real application. By applying the model to real world application, we should be able to explore the robustness of the research model and allows better understanding of the real-world application. The result of applying the model will be a readiness score for each case that shows where that specific healthcare organization is in terms of readiness for blockchain adoption as well as allow them to dive into each model element and learn how to improve their readiness. In achieving this, the model has been applied at to case studies. These two healthcare organizations are: Oregon Health & Science University (OHSU) and a large medical city in Saudi Arabia. These two cases would be a unique opportunity to examine how these healthcare organizations from two different countries and healthcare systems would be evaluated against the model parameters. In this section, a brief introduction of the case studies will be provided. In the following chapter, the results of the case studies and the sensitivity analysis will be presented.

7.1 Case Studies Introduction

7.1.1 Case 1: Oregon Health & Science University (OHSU)

Oregon Health & Science University (OHSU) is the state's only health and research university, and only academic health center. OHSU is one of Portland's largest employers with 17,532 employees and 4,739 students. OHSU serves 189,000 patients and is the source of more than 200 community outreach programs that bring health and education services to each county in the state. OHSU mission evolves around providing care for patients; educating doctors, nurses, dentists, pharmacists and other health care professionals; and conducting extensive research, including clinical trials to test new ways to prevent, detect and treat illness. OHSU is well advanced healthcare organization in terms of technological advancements with advanced research capabilities and active technology transfer center. OHSU tracks, explores, and keeps up with technological advancements and emerging technologies that potentially have positive impacts on patients care. For the case study development, an interview with an executive at the OHSU who possesses the academic and professional IT experience has been conducted and as a result the case study has been developed and the scores were assigned.

OHSU have undertaken various activities to explore blockchain technology. One initiative is the partnership with R/GA Ventures, a subsidiary of consultancy R/GA, and the state of Oregon to establish a new technology collaboration studio, with the goal of innovating blockchain technology, as well as creating a "blockchain ecosystem" in Oregon. The program is called Oregon Enterprise Blockchain Venture Studio (OEBVS). This initiative is headquartered at R/GA's Portland office. The program is backed by the state of Oregon and several organizations including Moda, Umpqua Bank, Portland State University, Oregon Health & Science University, Business Oregon, ConsenSys and blockchain research firm Smith and Crown. The goal of the program is to drive blockchain-led innovation. OEBVS will focus on developing startup-led products, services, and tools that can help Studio partners realize the full potential of blockchain technologies. Six blockchain companies are sponsored by the program working in a variety of industries including healthcare, finance, education, and more to establish a blockchain ecosystem. Patientory is the startup that represent the blockchain-based healthcare technology segment with the goal of working with Oregon healthcare organizations to build a blockchain ecosystem in healthcare and exchange experiences [267] [268].

7.1.2 Case 2: Medical City at Saudi Arabia

The second case study has been applied at one of the largest medical facilities in Saudi Arabia with a total capacity of more than 1000 beds. This medical city consists of few hospitals and medical centers. It has the capacity to treat, annually, more than 30,000 in-patients and more than half a million outpatients. It has the goal of implementing the best national and international standards to provide high quality services and has been recognized nationally and internationally for the state-of-the-art quality of care. It has developed a strong technology infrastructure throughout the recent years allowing it to be ranked among most technologically advanced healthcare organizations in the regions. These health IT solutions include the following interconnected systems as an example: EHR, EPHR, leave verification, and referral systems. It also tracks the new emerging technologies for potential adoption through various activities. However, its approach has been observed to be a cautious one. It rather to adopt proven technology. For the sake of this research, the identity of the healthcare organization has been asked to be anonymous by the health IT professional interviewed for this case. For the case study development, an interview with a consultant and health IT professional at this healthcare organization with the academic and professional IT experience has been conducted and as a result the case study has been developed and the scores were assigned.

Background on the Health IT landscape in Saudi Arabia

In the recent years, the health IT has gotten much attention and interest by the Saudi Arabian Ministry of Health and by recognized healthcare organizations. Most of the large hospitals in Saudi Arabia are owned, operated, and funded by the Saudi Arabian Ministry of Health. Healthcare organizations associated with the Ministry of National Guard, Armed Forces, Security Forces hospitals have made great progress in implementing Health II solutions such as EHR, and patient's engagement systems [269]. The healthcare services provided by the Ministry of health are offered to the citizens for free of charge and the most funds are directed toward building new healthcare facilities and covering the health care costs which in return made it harder in the past for the Ministry of Health to invest in costly health IT solutions. However, in the recent years the attention has been steered toward digitizing the healthcare system and taking advantage of the technological advancement in order to improve the healthcare system. The government of Saudi Arabia has provided unlimited support at all levels. Financial resources have been allocated and regulatory authorities has shown very great engagement.

The research publications examining the adoption and use of the health IT is still low. A study conducted to review the current literature about the E-Health status in Saudi

Arabia showed the E-Health growing attention. It showed also that the number of publications regarding health IT remains low [270]. El Mahalli examined the adoption and barriers to the use of an EHR system by nurses at three governmental hospitals [271]. The study findings showed underutilization of almost all the functionalities and features of the EHR among all hospitals. Also, the study revealed no utilization of any communication tools with patients. The top barriers cited in the study include lack of technical training/ support, increased workload, and system hanging up/ downtime issue. Khudair investigated the Saudi physicians' perspective toward EHR [272]. The results showed that Physicians emphasized the importance of accurate data organizations and archiving files. Also, physicians perceived the reasons behind the slow adoption of EHR by hospitals to the slow actions taken by the top management. However, IT managers perceived the physicians' readiness as a key success factor in the EHR implementation. Alsanea invistigated the future of health care delivery and the experience of a tertiary care center in Saudi Arabia [273]. He identified five technological advancements that would change the health care delivery as: digitalization of the PHR and data sharing, Increased accessibility through "Online Patient Services", preventive medicine Revisited, online patient education, and smart applications as counselors. Unfortunately, the number of publications examining the adoption and use of health IT solutions is very limited in Saudi Arabia due to the fact that it is very new landscape. Thus, more research is required.

7.1.3 Case Studies Selection Justification

Applying the research model to real world application helps in ensuring the robustness of the research model and allows better understanding of the real-world application. Case study is necessary to test applicability of the research. These two cases help understand how healthcare organizations would perform in the developed readiness model. The two cases selected are divers in nature. They are from two different healthcare systems. First case is the OHSU where healthcare is provided on pay-for-service base in an advanced healthcare systems. While the second case is from healthcare systemin an emerging region, Saudi Arabia, where government is committed to provide healthcare services free of charge to its citizens. Both cases have the potential to successfully adopt blockchain where as well blockchain would make sense to be adopted in these two cases. There is a very high potential for blockchain to add value in these two organizations where management of the EHR systems still developing and interoperability still pose a challenge. Apply the model would help test how the model would react based on the different natures of these two cases. Lastly, another reason for the selection is the cooperation and interest of these two healthcare organizations in exploring blockchain and apply the research model to test their readiness for adoption.

7.2 Analysis of the Case Studies and Sensitivity Analysis

In this chapter, the developed model will be applied to assess the overall readiness scores of two cases that were introduced in the previous section (section 7.1). A discussion with the experts from each case study has been conducted to assign the value curve scores for each healthcare organization with respect to each factor. The discussions with the experts took place using zoom meetings. The computation of the final readiness score is done using the mathematical equations discussed in chapter 5. Then scenarios analysis will be used to assess the model sensitivity and the ramifications on each case under each scenario. Finally, a discussion on how the model can be used to enhance the readiness score for each project will be provided and discussed.

7.2.1 Readiness Assessment Scores

The quantification of the model parameters and desirability metrics will remain constant but different blockchain projects will be tested against these results using their performance level based on assessing their adoption readiness on the desirability metrics scale. The different healthcare organization's levels on the metric scale will differ based on their readiness regarding each specific construct. For example, one healthcare organization may have a high level of knowledge and skills acquisition capabilities while another organization may fall short in this construct. It will be required to develop a higher capability level in which would improve its readiness level. Refer to the desirability curves discussion and readiness score computation in section 5.1.

The following tables show final readiness scores for each healthcare organization.

Table 60. Case1: Readiness Assessment Score

Perspective	Factor	Global Weight	Value Curve Score	Final Score
Financial Perspective	Budget Availability	7.07%	20	1.41
	Financial Risk & Uncertainty	7.05%	85	5.99
	Cost Saving	5.44%	80	4.36
Social Perspective	Talent & Knowledge acquisition	3.49%	85	2.97
	Stakeholder’s Awareness & Acceptance	2.76%	65	1.80
	Blockchain Ecosystem	2.63%	20	0.53

	Disintermediation & Business Process	2.66%	40	1.06
Technical Perspective	Infrastructure & Platform Integration	5.20%	85	4.42
	Standardization	5.53%	60	3.32
	Security and Privacy	8.49%	90	7.64
	Blockchain Maturity & Use Cases	5.20%	20	1.04
Organizational Perspective	Management Support	6.71%	70	4.70
	Training and Skills	3.26%	80	2.61
	HIT Strategy	5.54%	90	4.99
Regulations & legal Perspective	Regulation Compliance	10.81%	95	10.27
	Regulatory Uncertainty & Governance	9.69%	85	8.24
	Incentives Availability	8.45%	20	1.69
	Total	100%		**67.029**

Table 61. Case2: Readiness Assessment Score

Perspective	Factor	Global Weight	Value Curve Score	Final Score
Financial Perspective	Budget Availability	7.07%	100	7.07
	Financial Risk & Uncertainty	7.05%	50	3.52
	Cost Saving	5.44%	50	2.72
Social Perspective	Talent & Knowledge acquisition	3.49%	35	1.22
	Stakeholder's Awareness & Acceptance	2.76%	70	1.93
	Blockchain Ecosystem	2.63%	70	1.84
	Disintermediation & Business Process	2.66%	70	1.86
Technical Perspective	Infrastructure & Platform Integration	5.20%	70	3.64
	Standardization	5.53%	35	1.94
	Security and Privacy	8.49%	70	5.94
	Blockchain Maturity & Use Cases	5.20%	10	0.52
Organizational Perspective	Management Support	6.71%	85	5.70
	Training and Skills	3.26%	70	2.28
	HIT Strategy	5.54%	90	4.99
Regulations & legal Perspective	Regulation Compliance	10.81%	80	8.65
	Regulatory Uncertainty & Governance	9.69%	60	5.82
	Incentives Availability	8.45%	50	4.23
	Total	100%		**63.884**

7.2.2 Strengths and Weaknesses

The following table highlights the strengths and weaknesses of each healthcare organization with regards to blockchain adoption readiness. This comparison shows how the model was able to capture different attributes that contribute to case and better understand the dynamics of each contributing factors.

Table 62. Strengths and Weaknesses for each Scenario

Case 1	Factor	Factor Score	Value
Strengths	Regulation Compliance	Dedicated experienced legal and technology transfer teams are involved to guide the adoption effort and comply with regulations and policies.	95
	HIT Strategy	Advanced to Mature Strategy	90
	Security and Privacy	Advanced Security and Privacy expertise	90
Weaknesses	Budget Availability	Limited budget	20
	Blockchain Ecosystem	Limited interaction with Blockchain Ecosystem entities; no cooperation	20
	Blockchain Maturity & Use Cases	Learning programs with collaboration with other entities to share knowledge efforts.	20
	Incentives Availability	No incentives; Low level of collaboration	20
Case 2	**Factor**	**Factor Score**	**Value**
Strengths	Budget Availability	High Budget (there is a very high commitment)	100
	HIT Strategy	Medium to high maturity level	90
	Management Support	Enthusiastic (supportive)	85
	Regulation Compliance	Dedicated experienced legal and technology transfer teams are involved guide the effort and comply with regulations and policies.	80
Weaknesses	Blockchain Maturity & Use Cases	Very minimum efforts have been undertaken	10
	Standardization	Minimum standards exist	35
	Talent & Knowledge acquisition	Low level	35

For both cases, there are many areas where they ranked high in terms of their readiness and capabilities for blockchain adoption. However, there are plenty of opportunities to enhance their readiness for blockchain adoption. For case 1, OHSU has a very strong and dedicated technology transfer and legal team that work closely with all the health IT projects to ensure they comply with regulation and laws. Also, OHSU has a clear and mature health IT strategy where any health IT project should be in alignment with the OHSU's health IT strategy and the objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem. OHSU takes pride in the security their systems enjoy. OHSU ranked high in the security expertise level. On the other hand, OHSU has ranked low in multiple areas. OHSU provides limited budget especially with the dramatic impact of Covid-19. The participation in the blockchain ecosystem is another weakness where OHSU has limited interaction with blockchain Ecosystem entities with no visible cooperation. Currently, OHSU's blockchain effort are limited to learning programs with collaboration with other entities to share knowledge. More effort to enhance the understanding of the technology as well as building use cases and small project is needed. Currently, there are no official incentives but there is a very low level of collaboration with other partners to incentive the adoption. For case 2, budget availability ranked high and that mainly due to the focus of the government and ministry of health in digitizing the healthcare sector as well as the support to implement the technologies that could improve the quality of care provided. For this factor, healthcare organization is realizing the importance and relevance of the project and committed to providing the needed financial resources for the execution and long-term support commitment. Similar to OHSU, case 2 show that it has a clear and mature health IT strategy where any health IT project should be in alignment with the health IT strategy and the objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem. Management support was ranked high due to the support they get to undertake such project from the government. Moreover, the regulatory landscape in Saudi Arabia has much more flexibility that it could understand and interact with the emerging technologies easily. Healthcare organizations enjoy high level of interaction with regulatory authorities and possibly could propose new laws and policies in order to facilitate the adoption of technologies that potentially contribute to better healthcare system. Case 2 ranked high in the regulation compliance factors as the healthcare organization has an experienced team to guide the adoption process. On the other hand, it scores low in blockchain maturity & use cases, standardization, and Talent & Knowledge acquisition factors.

The two cases have been explored separately since the objective of this research is not to compare projects but to test and examine each case and assign a readiness score for each one independently. However, when examining them together we could have a better idea on how healthcare organizations with similar characteristics would possibly react and rank. It would help better understand the healthcare industry landscape interaction with blockchain and where the efforts should be directed.

Table 63 below highlights the strengths and weaknesses of both healthcare organizations combined. The goal is to understand the areas that both cases have scored very well and the areas that both cases scored low with regards to blockchain adoption readiness. This comparison provides better understanding of how healthcare organizations would interact with the adoption factors and how healthcare organizations with similar characteristics have high likelihood to score similarly.

Table 63. Strengths and Weaknesses of the two cases combined

Both	Factor	Factor Score
Strengths	Regulation Compliance	Mature to dedicated experienced legal and technology transfer teams are involved to guide the adoption effort and comply with regulations and policies.
	HIT Strategy	Advanced to Mature Strategy
	Security and Privacy	Advanced Security and Privacy expertise and technical infrastructures
	Management Support	Good to Enthusiastic Support
Weaknesses	Blockchain Maturity & Use Cases	Minimum Efforts - Learning programs and collaboration with other entities to share knowledge efforts.
	Incentives Availability	No incentives; Low level of collaboration
	Blockchain Ecosystem	Limited interaction with Blockchain Ecosystem entities with limited cooperation
	Standardization	Minimum to medium standards exist

For both cases combined, there are many areas where they scored high in terms of their readiness and capabilities for blockchain adoption. Both cases have a mature to dedicated experienced legal and technology transfer teams that are involved in guiding the adoption effort and comply with regulations and policies. The fitness and alignment of blockchain adoption in the healthcare IT strategy is very significant adoption determinant which both healthcare organizations have scored high on. The two healthcare organizations have an advanced security and privacy expertise as well as technical infrastructures that help enable seamless adoption. Also, top management in both cases have shown strong support to such an initiative. On the other side, both healthcare organizations have scored low in certain areas and shown weakness. With regards to the blockchain maturity and use cases, both healthcare organizations have showed minimum efforts to enhance their understanding of the technology and their current efforts are limited to learning programs and collaboration with other entities to share knowledge efforts without any reported blockchain use cases or projects. Also, at this point there is no incentives provided to encourage the blockchain adoption from official authorities with low level of collaboration with authorities and partners to set up technical and financial incentives. Blockchain relies in the participation of the partners which in this case both healthcare organizations have a limited interaction with Blockchain Ecosystem entities with limited cooperation. Finally, the two healthcare organizations scored low in the standardization factor where there are minimum to medium standards exist. Healthcare organizations could certainly overcome these areas of weakness by collaborating to advance the knowledge and the understanding of the technology and its capabilities. Efforts to collaborate in developing blockchain projects ensure successful adoption and reap the benefits of such a remarkable technology.

7.2.3 Scenario Analysis

Technology evolves, and the decisions around them change. blockchain technology is an emerging technology, and its maturity is growing and the regulations around it continue to mature as well. This research is conducted at one point in time and it is crucial to provide insights into how the outcomes of this research would be impacted by changing priorities. Thus, there is a need to develop a model that can adapt to such changes. Sensitivity analysis is used to analyze the impacts of potential changes in the values at any level of the HDM as discussed in chapter 5. Also, It is used to gauge the robustness of the model and the change in rank priorities under foreseeable circumstances [215]. Sensitivity analysis gives a clear picture of how each level and its components relate to each other. SA suggests using multiple scenarios to test how much the ranking would be altered in a particular setting. Furthermore, different scenarios can be used to test the sensitivity of the model to changes in order to calculate how much perturbation in its priorities a model would endure before producing different results. This is done when the decision-maker believes that the importance of a specific perspective level changes. Each scenario changes the relevance of perspectives by boosting one perspective a time. For example, we boost the Financial perspective to be 0.96, while the rest of the perspective's values set to be 0.01 for each and repeat the process for the other perspectives. This method has been used widely in several previous dissertations [177] [176] [175] [172]. In this analysis, five scenarios are suggested, in each scenario, one of the perspectives is boosted with the assumption that it might turn out in reality that this is the most critical perspective (see Table 60). The results show that there are ranking changes in the first, second, and fourth scenarios. This change is due to the assumption of extreme scenarios. However, in practice the changes would most likely be much less extreme. Yet, the changes are not considered as significant. It is observed that a positive/favorable changes occurred on the areas where these two cases performed well.

Table 64. Future Scenarios

Perspective	Financial	Social	Organizational	Technical	Legal
Base	19.4%	11.6%	15.4%	24.4%	29%
Scenario 1: Financial Emphasis	**96.0%**	1.0%	1.0%	1.0%	1.0%
Scenario 2: Social Emphasis	1.0%	**96.0%**	1.0%	1.0%	1.0%
Scenario 3: Technical Emphasis	1.0%	1.0%	**96.0%**	1.0%	1.0%
Scenario 4: Organizational Emphasis	1.0%	1.0%	1.0%	**96.0%**	1.0%
Scenario 5: Regulations & Legal Emphasis	1.0%	1.0%	1.0%	1.0%	**96.0%**

In the first scenario, the financial perspective has been boosted to the maximum value of 96%. The result shows that the overall score for case 1 decreased from 67.03 to 60.78 while case 2 increased from 63.88 to 68.33. The favorable change for case 2 suggests that that if there are indications that financial perspective factors are shown to be the most critical factors in reality, then it can be done with more confidence. The ranking has changed as well. The below table demonstrates the changes in the overall score for both cases and the changes in financial perspective scores.

Table 65. Scenario 1: Financial Emphasis

Scenario 1: Financial Emphasis (boosted to 0.96)					
Perspective	Factor	Local Weight	Global Weight	Case 1 Score	Case 2 Score
Financial Perspective	Budget Availability	36.4%	34.92%	6.98	34.92
	Financial Risk & Uncertainty	36.3%	34.80%	29.58	17.40
	Cost Saving	28.0%	26.88%	21.50	13.44
Social Perspective	Talent & Knowledge acquisition	30.20%	0.30%	0.26	0.11
	Stakeholder’s Awareness & Acceptance	23.90%	0.24%	0.16	0.17
	Blockchain Ecosystem	22.80%	0.23%	0.05	0.16
	Disintermediation & Business Process	23.00%	0.23%	0.09	0.16
Technical Perspective	Infrastructure & Platform Integration	21.27%	0.21%	0.18	0.15
	Standardization	22.64%	0.23%	0.14	0.08
	Security and Privacy	34.73%	0.35%	0.31	0.24
	Blockchain Maturity & Use Cases	21.27%	0.21%	0.04	0.02
Organizational Perspective	Management Support	43.44%	0.43%	0.30	0.37
	Training and Skills	21.11%	0.21%	0.17	0.15
	HIT Strategy	35.89%	0.36%	0.32	0.32
Regulations & legal Perspective	Regulation Compliance	37.29%	0.37%	0.35	0.30
	Regulatory Uncertainty & Governance	33.43%	0.33%	0.28	0.20
	Incentives Availability	29.14%	0.3%	0.06	0.15
	Total		100.60%	**60.78**	**68.33**

Scenario 1: Financial Emphasis		
	Case 1	Case 2
	Score Change	

Original	67.03	63.88
Scenario	60.78	68.33
Change	-6.25	4.45
	Ranking Change	
Original	1	2
Scenario	2	1

In the scenario s, the social perspective has been boosted to the maximum value of 96%. The result shows that the overall score for case 1 decreased from 67.03 to 55.54 and case 2 decreased as well from 63.88 to 59.65. Both cases were negatively affected. These changes suggest that that if there are indications that social perspective factors are shown to be the most critical factors in reality, then the readiness score is to be negatively impacted and special considerations should be in place to improve the organizations capabilities in these areas. The ranking has changed as well. The below table demonstrates the changes in the overall score for both cases and the changes in social perspective scores.

Table 66. Scenario 2: Social Emphasis

Scenario 2: Social Emphasis (boosted to 0.96)					
Perspective	Factor	Local Weight	Global Weight	Case 1 Score	Case 2 Score
Financial Perspective	Budget Availability	36.4%	0.4%	0.07	0.36
	Financial Risk & Uncertainty	36.3%	0.4%	0.31	0.18
	Cost Saving	28.0%	0.3%	0.22	0.14
Social Perspective	Talent & Knowledge acquisition	30.20%	29.0%	24.64	10.15
	Stakeholder’s Awareness & Acceptance	23.90%	22.9%	14.91	16.06
	Blockchain Ecosystem	22.80%	21.9%	4.38	15.32
	Disintermediation & Business process	23.00%	22.1%	8.83	15.46
Technical Perspective	Infrastructure & Platform integration	21.27%	0.2%	0.18	0.15
	Standardization	22.64%	0.2%	0.14	0.08
	Security and Privacy	34.73%	0.3%	0.31	0.24
	Blockchain Maturity & Use Cases	21.27%	0.2%	0.04	0.02
Organizational Perspective	Management Support	43.44%	0.4%	0.30	0.37
	Training and Skills	21.11%	0.2%	0.17	0.15
	HIT Strategy	35.89%	0.4%	0.32	0.32

Regulations & legal Perspective	Regulation Compliance	37.29%	0.4%	0.35	0.30
	Regulatory Uncertainty & Governance	33.43%	0.3%	0.28	0.20
	Incentives Availability	29.14%	0.3%	0.06	0.15
	Total		100%	**55.54**	**59.65**

Scenario 2: Social Emphasis		
	Case 1	Case 2
	Score Change	
Original	67.03	63.88
Scenario	55.54	59.65
Change	-11.49	-4.24
	Ranking Change	
Original	1	2
Scenario	2	1

In the scenario 3, the technical perspective has been boosted to the maximum value of 96%. The result shows that the overall score for case 1 increased from 67.03 to 67.13 while case 2 negatively impacted which resulted in a decrease from 63.88 to 50.043. The favorable change for case 1 suggests that that if there are indications that technical perspective factors are shown to be the most critical factors in reality, then it can be done with more confidence. Also, case 1 have shown that it has more technical capabilities in reality than case 2. The ranking has not changed. The below table. demonstrates the changes in the overall score for both cases and the changes in technical perspective scores.

Table 67. Scenario 3: Technical Emphasis

Scenario 3: Technical Emphasis (boosted to 0.96)					
Perspective	Factor	Local Weight	Global Weight	Case 1 Score	Case 2 Score
Financial Perspective	Budget Availability	36.38%	0.4%	0.07	0.36
	Financial Risk & Uncertainty	36.25%	0.4%	0.31	0.18
	Cost Saving	28.00%	0.3%	0.22	0.14
	Talent & Knowledge acquisition	30.20%	0.3%	0.26	0.11

Social Perspective	Stakeholder's Awareness & Acceptance	23.90%	0.2%	0.16	0.17
	Blockchain Ecosystem	22.80%	0.2%	0.05	0.16
	Disintermediation & Business process	23.00%	0.2%	0.09	0.16
Technical Perspective	Infrastructure & Platform integration	21.27%	20.4%	17.36	14.30
	Standardization	22.64%	21.7%	13.04	7.61
	Security and Privacy	34.73%	33.3%	30.00	23.34
	Blockchain Maturity & Use Cases	21.27%	20.4%	4.08	2.04
Organizational Perspective	Management Support	43.44%	0.4%	0.30	0.37
	Training and Skills	21.11%	0.2%	0.17	0.15
	HIT Strategy	35.89%	0.4%	0.32	0.32
Regulations & legal Perspective	Regulation Compliance	37.29%	0.4%	0.35	0.30
	Regulatory Uncertainty & Governance	33.43%	0.3%	0.28	0.20
	Incentives Availability	29.14%	0.3%	0.06	0.15
	Total		100%	**67.13**	**50.04**

Scenario 3: Technical Emphasis		
	Case 1	Case 2
	Score Change	
Original	67.03	63.88
Scenario	67.13	50.04
Change	0.10	-13.84
	Ranking Change	
Original	1	2
Scenario	1	2

In the scenario 4, the organizational perspective has been boosted to the maximum value of 96%. The result shows that the overall score for case 1 increased from 67.03 to 78.94 and case 2 increased as well from 63.88 to 83.06. The favorable change for case 1 and case 2 suggests that that if there are indications that the organizational perspective factors are shown to be the most critical factors in reality, then both cases can be done with more confidence. Also, case 1 and case 2 have scored high in reality for this perspective. The ranking has changed. The following table demonstrates the changes in the overall score for both cases and the changes in the organizational perspective scores.

Table 68. Scenario 4: Organizational Emphasis

Scenario 4: Organizational Emphasis (boosted to 0.96)					
Perspective	Factor	Local Weight	Global Weight	Case 1 Score	Case 2 Score
Financial Perspective	Budget Availability	36.38%	0.4%	0.07	0.36
	Financial Risk & Uncertainty	36.25%	0.4%	0.31	0.18
	Cost Saving	28.00%	0.3%	0.22	0.14
Social Perspective	Talent & Knowledge acquisition	30.20%	0.3%	0.26	0.11
	Stakeholder's Awareness & Acceptance	23.90%	0.2%	0.16	0.17
	Blockchain Ecosystem	22.80%	0.2%	0.05	0.16
	Disintermediation & Business process	23.00%	0.2%	0.09	0.16
Technical Perspective	Infrastructure & Platform integration	21.27%	0.2%	0.18	0.15
	Standardization	22.64%	0.2%	0.14	0.08
	Security and Privacy	34.73%	0.3%	0.31	0.24
	Blockchain Maturity & Use Cases	21.27%	0.2%	0.04	0.02
Organizational Perspective	Management Support	43.44%	41.7%	29.19	35.45
	Training and Skills	21.11%	20.3%	16.21	14.19
	HIT Strategy	35.89%	34.5%	31.01	31.01
Regulations & legal Perspective	Regulation Compliance	37.29%	0.4%	0.35	0.30
	Regulatory Uncertainty & Governance	33.43%	0.3%	0.28	0.20
	Incentives Availability	29.14%	0.3%	0.06	0.15
	Total		100%	**78.94**	**83.06**

Scenario 4: Organizational Emphasis		
	Case 1	Case 2
	Score Change	
Original	67.03	63.88
Scenario	78.94	83.06
Change	11.91	19.18
	Ranking Change	
Original	1	2
Scenario	2	1

In the scenario 4, the regulations & legal perspective has been boosted to the maximum value of 96%. The result shows that the overall score for case 1 increased from 67.03 to 69.50 and case 2 increased as well from 64.49 to 83.06. The favorable change for case 1 and case 2 suggests that that if there are indications that the organizational perspective factors are shown to be the most critical factors in reality, then both cases can be done with more confidence. Also, case 1 and case 2 have scored well in reality for this perspective. The ranking has changed. The following table demonstrates the changes in the overall score for both cases and the changes in the regulations & legal perspective scores.

Table 69. Scenario 5: Regulations & Legal Emphasis

Scenario 5: Regulations & Legal Emphasis (boosted to 0.96)					
Perspective	Factor	Local Weight	Global Weight	Case 1 Score	Case 2 Score
Financial Perspective	Budget Availability	36.4%	0.4%	0.07	0.36
	Financial Risk & Uncertainty	36.3%	0.4%	0.31	0.18
	Cost Saving	28.0%	0.3%	0.22	0.14
Social Perspective	Talent & Knowledge acquisition	30.2%	0.3%	0.26	0.11
	Stakeholder's Awareness & Acceptance	23.9%	0.2%	0.16	0.17
	Blockchain Ecosystem	22.8%	0.2%	0.05	0.16
	Disintermediation & Business process	23.0%	0.2%	0.09	0.16
Technical Perspective	Infrastructure & Platform integration	21.3%	0.2%	0.18	0.15
	Standardization	22.6%	0.2%	0.14	0.08
	Security and Privacy	34.7%	0.3%	0.31	0.24
	Blockchain Maturity & Use Cases	21.3%	0.2%	0.04	0.02
Organizational Perspective	Management Support	43.4%	0.4%	0.30	0.37
	Training and Skills	21.1%	0.2%	0.17	0.15
	HIT Strategy	35.9%	0.4%	0.32	0.32
Regulations & legal Perspective	Regulation Compliance	37.3%	35.8%	34.00	28.64
	Regulatory Uncertainty & Governance	33.4%	32.1%	27.28	19.25
	Incentives Availability	29.1%	28.0%	5.60	13.99
	Total		100%	**69.50**	**64.49**

Scenario 5: Regulations Emphasis		
	Case 1	Case 2
	Score Change	
Original	67.03	63.88
Scenario	69.50	64.49
Change	2.47	0.61
	Ranking Change	

Original	1	2
Scenario	1	2

All the changes could inform decision makers on how to proceed with their efforts towards improving their capabilities for blockchain adoption.

7.2.4 Suggested Improvement of the Readiness Score

The goal of this research is to provide a model that can help healthcare organizations assess their readiness for the blockchain adoption, identify and rank the most important factors in the adoption, and identify weaknesses that might hinder the success of the project. It will allow healthcare organization make improvements and corrective steps based on the identified weaknesses. The strengths and weakness section of this chapter discussed each case and the areas of weakness and strength. In this section, a demonstration on how this research model can add value and improve the readiness score in order to improve the success chances. The goal of the research is not only to identify weaknesses but also to go a step further to offer guidelines and recommendations on how to improve it as well. The enhancements will target the areas where the organizations have scored low and provide appropriate recommendations. The following tables present possible enhancements for both cases based on their scores. Healthcare organizations would approach them conservatively, moderately, or go all in and make dramatic changes. The project manager will consult value curves to identify where they are now and what is the next level for each model element and what is the optimal level for that specific factor. It could be used as a process where the change can start as conservative one and move one step up until the score and the confidence on the readiness is achieved.

Table 70. Case1: Suggested Enhancements

Case 1							
Perspective	**Factor**	**Weight**	**VC Score**	**Score**	**New VC Score**	**New Score**	**Action**
Financial Perspective (0.194)	Budget Availability	7.07%	20	1.41	60	4.24	Seek more financial resource allocation
	Financial Risk & Uncertainty	7.05%	85	5.99	85	5.99	No Action
	Cost Saving	5.44%	80	4.36	80	4.36	No Action
Social Perspective (0.116)	Talent & Knowledge acquisition	3.49%	85	2.97	85	2.97	No Action
	Stakeholder's Awareness & Acceptance	2.76%	65	1.80	90	2.49	Seek more involvement from stakeholders and provide the necessary blockchain education
	Blockchain Ecosystem	2.63%	20	0.53	60	1.58	Leverage the existing connections with Health IT and Blockchain ecosystem at the state level
	Disintermediation & Business process	2.66%	40	1.06	70	1.86	Work on making more adjustment to the existing business process in order to eliminate nonvalue generating processes
Technical Perspective (0.244)	Infrastructure & Platform integration	5.20%	85	4.42	85	4.42	No Action
	Standardization	5.53%	60	3.32	60	3.32	No Action
	Security and Privacy	8.49%	90	7.64	90	7.64	No Action

	Blockchain Maturity & Use Cases	5.20%	20	1.04	60	3.12	Start working on developing use cases, prototypes, and small project.
Organizational Perspective (0.154)	Management Support	6.71%	70	4.70	70	4.70	No Action
	Training and Skills	3.26%	80	2.61	80	2.61	No Action
	HIT Strategy	5.54%	90	4.99	90	4.99	No Action
Regulations & legal Perspective (0.290)	Regulation Compliance	10.81%	95	10.27	95	10.27	No Action
	Regulatory Uncertainty & Governance	9.69%	85	8.24	85	8.24	No Action
	Incentives Availability	8.45%	20	1.69	20	1.69	No Action
		Results		**67.03**		**74.48**	

Table 71. Cases 2: Suggested Enhancements

Case 2							
Perspective	**Factor**	**Weight**	**VC Score**	**Score**	**New VC Score**	**New Score**	**Action**
Financial Perspective (0.194)	Budget Availability	7.07%	100	7.07	100	7.07	No Action
	Financial Risk & Uncertainty	7.05%	50	3.52	80	5.64	Develop a more robust risk assessment plan with all the necessary measurements
	Cost Saving	5.44%	50	2.72	65	3.54	Conduct cost-benefits analysis and have well developed and determined financial saving goals
Social Perspective (0.116)	Talent & Knowledge acquisition	3.49%	35	1.22	70	2.44	Develop a clear strategy in acquiring knowledge and skilled and relevant talents
	Stakeholder's Awareness & Acceptance	2.76%	70	1.93	70	1.93	No Action

	Blockchain Ecosystem	2.63%	70	1.84	70	1.84	No Action
	Disintermediation & Business process	2.66%	70	1.86	70	1.86	No Action
Technical Perspective (0.244)	Infrastructure & Platform integration	5.20%	70	3.64	70	3.64	No Action
	Standardization	5.53%	35	1.94	60	3.32	Improve the level of standards to accommodate the adoption of such a technology
	Security and Privacy	8.49%	70	5.94	70	5.94	No Action
	Blockchain Maturity & Use Cases	5.20%	10	0.52	70	3.64	Develop a learning programs and collaborate with other entities to share knowledge and build use cases
Organizational Perspective (0.154)	Management Support	6.71%	85	5.70	85	5.70	No Action
	Training and Skills	3.26%	70	2.28	70	2.28	No Action
	HIT Strategy	5.54%	90	4.99	90	4.99	No Action
Regulations & legal Perspective (0.290)	Regulation Compliance	10.81%	80	8.65	80	8.65	No Action
	Regulatory Uncertainty & Governance	9.69%	60	5.82	60	5.82	No Action
	Incentives Availability	8.45%	50	4.23	70	5.92	Work with regulators and partners to provide incentives
		Results		**63.88**		**74.23**	

CHAPTER 8: RESEARCH VALIDITY

The goal of the research validation is to ensure that the research model has captured the most important factors impacting the adoption of the blockchain technology and is valid for application. The research will use three validity measures, namely: construct validity, content validity, and criterion-related validity in order to achieve valid and reliable results. The following table illustrates each validity measures characteristics followed by discussion of each one:

Table 72. The validity measures characteristics

Validity	Description	Method	When
Construct validity	Degree to which a proposed research approach complies with its underlying theories. Is the model correct and capable of serving as an assessment tool?	Expert evaluation	Model development and data collection
Content validity	Degree to which a measure represents a given domain of interest and will test the how ready the instruments for data collection.	Expert evaluation, and literature review	During the model Development
Criterion-related validity	Degree of effectiveness of the model in performing well and predicting real life phenomenon. (Review of the results by the experts and examining whether they are accurate and valid).	Expert evaluation	After the analyses

This research has followed previous successful dissertations that have discussed the research validity [168], [172], [175], [176], [177], [178], [187], [188], [189].

8.1 Construct Validity

One important validation measure, Construct Validity, that has been undertaken to validate the research model was done as part of a pilot study in the comprehensive exam. Construct Validity refers to the fitness of the research approach to past the underlying theories as well as the ability of the model's structure to deal with the problem at hand. On other words, it tests the readiness of the instruments to gather data from respondents.

In this research, the initial decision model that has been developed base on the review of the literature is tested using inputs from several Ph.D. students in technology management before moving forward. Students were asked to participate and act as experts in piloting the research model. They were asked to validate the model constructs and desirability metrics as well as quantifying both the model and desirability curves. The validation of the model and desirability metrics as well as the quantification of the desirability metrics have been done using the Qualtrics survey while the quantification of the model was done using the HDM software. The results of this step showed the ability of the model's structure to deal with the problem at hand as well as the validity of the initial model to be used as an effective instrument to gather data from respondents.

8.2 Content Validity

Content validity refers to the ability of the model contents to properly represent all relevant aspects pertaining to the research topic. It ensures that the most important factors have been included in the model, and the model best represents the reality. Content validity was conducted during the model development phase. In this case, subject matter experts have been identified and contacted to validate the model element using a validation surveys vis Qualtrics software. The experts chosen to validate the model should have deep knowledge in the blockchain technology, come from different backgrounds, and possess different experiences. An extensive discussion on the expert's identification, selection, and panels formation was provided in section 5.2. Thirty subject matter experts have participated in this phase. The experts had the freedom to suggest edits to the model, remove items, add, or propose new items or sort and organize items within the model in a different fashion. Seven expert panels in the area of blockchain have validated the model perspectives, factors under each perspective, and desirability metrics definitions. In order to validate the items successfully, at least two/third (67%) of the experts in the validation experts' panel should indicate that the perspective or factor is essential. Higher levels of validity are achieved as more expert panel members agree on the items to be included in the model. A special attention should be given to the validation process to ensure reliable results as well as a generalizable model. The results of the content validity are discussed in chapter 6.

8.3 Criterion-Related Validity

Criterion-related validity takes place in the final stage of the research and after the model is applied and during the results analysis. It refers to the validity of the research outcomes and its ability to accurately describe the situation being studied. It measures the degree of effectiveness of the model in performing well and predicting real life phenomenon. It involves the review of the results by the experts and examining whether they are accurate and valid.

The quantified model has been tested against two case studies and subject matter experts were asked to determine if the results were acceptable. To conduct this validation, two case studies have been selected to be assessed for readiness using the research model in order to show how the model can be used and what value it brings. The results of conducting the case studies (see chapter 7) were shared with the healthcare organizations the model was applied at to ask them if the assessment framework is appropriate enough for evaluating blockchain adoption readiness in which they found it to be helpful and appropriate.

8.4 The Generalizability of the Research Model

To validate and quantify the research model, expert with deep knowledge of the blockchain technology, who come from different backgrounds, and possess different experiences were invited to participate in the research in which have ensured high level of generalizability of the model and allows greater acceptance and applicability of the model in other organizational settings. Furthermore, experts have been asked to verify if the model could be generalized to other than the case study applications and they confirmed its appropriateness to be used as an assessment tool. The model as well was tested against two case studies and the healthcare organization found it to be an effective tool for readiness assessment.

Various validity measures have been utilized to ensure reliable results and generalizable model such as inconsistency in expert judgments, disagreement among expert panel members, and the sensitivity analysis to analyze the impacts of potential changes in the values of the different levels of the HDM and gauge the robustness of the model and the change in rank priorities under foreseeable circumstances.

It is essential though to understand that the generalizability of the results derived from the research is context and time dependent meaning that at any time in the future the Financial, Social, Organizational, Technical, and Regulations & Legal factors may not be in the same state as at the time of this study.

CHAPTER 9: DISCUSSION

This chapter provides a discussion of key findings from: validation, quantification, and case studies.

9.1 Practical Application: General

The problem statement (chapter1) suggests that there is a high rate of blockchain project failure and struggles to achieve blockchain goals. Katuwal et al. investigated blockchain literature to explore blockchain technology applications, and implementations in management of patient records. Katuwal et al. concluded that most of current blockchain projects are: white-papers, proof of concepts, and products with a limited user base [17].

Blockchain implementations have been struggling to succeed. Blockchain is an emerging technology. Current models of blockchain are: immature, can be challenging to scale, poorly understood, and unproven in mission-critical [18] environments. However, blockchain is maturing rapidly and recent implementations are moving quickly beyond the pilot and proof of concept phase [19].

Business challenges of blockchain are often more significant than those posed by blockchain technology [20]. Recent reports show that a high number of blockchain projects are either shutting down or scaling back in terms of goals and timelines [22]. It is estimated that 90% of projects will not survive to be operational [22]. Forrester tracked 43 blockchain projects that referenced blockchain as revolutionary in their respective industries and concluded that none of the projects had achieved their full implementation objectives [23]. According to the VP of the Forrester, “In 2018, we expect to see a number of projects stopped that should never have been started in the first place.” [24].

A comprehensive literature review has been conducted to identify and investigate existing literature related to assessment of the blockchain technology adoption for management of Electronic Health Records (EHR) systems. This research explored: methodologies, approaches, theories, and practices; that have been used by healthcare providers in the management of patient records. This research also explored recent implementations and frameworks of blockchain in healthcare. Blockchain technology as a new concept emerged in recent years as a new platform that facilitates management and exchanges of patient records. As discussed in the gap analysis (chapter 3), there is a lack of, and a need for, research that addresses and evaluates factors impacting blockchain technology adoption for management of the EHR, in a structured and systematic way.

This research utilized inputs from more than 60 blockchain subject matter experts. The experts chosen to validate the model had deep knowledge in: blockchain technology, come from different backgrounds, possess different experiences, and have different exposure to the topic. Thirty experts were invited to validate the research model. They confirmed that there is a need for a readiness assessment tool. The experts validated 17 factors as important in the assessment of blockchain technology adoption. The validation phase confirmed that the structure and model elements are appropriate for evaluating blockchain technology adoption.

38 experts were invited to quantify the research model and assign weights for perspectives. The level of perspectives and the factors within each perspective were also

assigned weights and quantified. Based on experts' judgments, the quantification phase of the model generated important insights. The results suggest that the regulations & legal perspective is the most important perspective. This perspective holds the highest relative weight with 29%. Blockchain technology is new and the regulations around it are still immature. Healthcare organizations are working on understanding these regulations and how blockchain can comply with existing regulations and laws.

Healthcare organizations are exploring how to implement blockchain while complying with current regulations and current governance strategies. The technical perspective came in second regarding level of importance, in relation to other perspectives, with relative weight of 24.4%. The third perspective is the financial perspective with relative weight of 19.4%, followed by the organizational perspective with relative weight of 14.5%. The least important perspective is the social perspective with relative weight of 11.6%.

9.2 Practical Application: Financial Perspective

In the financial perspective, three factors have been validated as important and quantified by experts. These factors are: Budget Availability, Financial Risk & Uncertainty, and Cost Saving. The financial factors quantification results show that Budget Availability and Financial Risk & Uncertainty factors are tied for the most important factors with 36.38% and 36.25% respectively (both factors ranked in the top overall factors in the terms of their importance to the overall model). Cost Saving ranked as the third most important factor in the financial perspective.

For a successful blockchain adoption, healthcare organizations should be committed to dedicate and provide sufficient funds for blockchain projects, as well as; having budget flexibility with other associated costs, such as: initial costs, and participation costs [94] [274] [275] [276] [277]. Blockchain is in an early stage of its maturity as well as the complexity and scarcity of its implementations. Knowledge of its related financial costs is under investigation. The number of real-world projects is limited, and the costs associated with implementation are hard to be fully determined. Healthcare organizations should be able to deal with the uncertainty of and anticipate various costs associated with getting the technology into operation, such as: expanding the blockchain network, cost of transactions, maintenance, and scalability [80] [278] [146].

In terms of cost saving, many healthcare organizations are waiting for proven return on investment measurements before moving on into adopting blockchain solutions. Healthcare organizations are failing to recognize the substantial return on investment blockchain offers. Cost reduction could come from: automation of intense human actions, avoidance of costly errors, getting rid of unnecessary intermediaries, record duplication reduction, and data collection time and effort reduction [54] [68] [69] [72] [75] [76] [78] [105] [147]. Healthcare organizations should engage in cost benefits analysis and determine financial saving goals from the implementation of blockchain using quantification techniques and measurements. The three aforementioned financial factors have been validated as important factors and weighted differently in their importance in the adoption. Healthcare organizations should understand their financial dynamics and address them in order to have a successful adoption.

9.3 Practical Application: Social Perspective

For the social perspective, four factors have been validated as important and quantified by experts. These factors are: Talent & Knowledge acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Business Process. The social factors quantification results show that the Talent & Knowledge acquisition factor is the most important factor with relative a importance of 30.2%. The second most important factor under the social perspective is the Stakeholder's Awareness & Acceptance factor with a relative importance of 23.9% followed by Disintermediation & Business Process with a relative importance of 23%. The least important factor in the social perspective is the Blockchain Ecosystem with a relative importance of 22.8%.

Because of the nascency and immaturity of the blockchain technology, and the continuous changes and developments in the technology landscape, healthcare organizations are currently required to have a high level of talent and knowledge acquisition capabilities. Literature suggests that there is a lack of sufficient skills and talents in the market for blockchain development. The blockchain ecosystem is yet to address this problem effectively. A survey of more than 100 executives showed that the struggle to acquire talent is most pronounced in areas, or sub-areas, related to blockchain [153]. The same survey states that the demand for blockchain talent is growing at over 40% per quarter [153]. Healthcare organizations need to keep up with the knowledge and development of blockchain technology as well as attract necessary talents (people) to implement and operate the blockchain projects [67] [149] [150] [154].

The awareness of the blockchain technologies potential to disrupt the healthcare system, and solve many of the current healthcare issues, should be understood by the different stakeholders within different levels of healthcare organizations [21] [99] [150] [274]. The challenge with blockchain adoption is more educational than technical. As a result of educational issues inadequate realization of blockchain relevance including its ensuing benefits are unrealized.

One of the largest external roadblocks to adoption is working with partners and ecosystem members. It is challenging to get market participants to join a blockchain network. Getting organizations together to advance shared objectives for technology and create an environment of shared value is among the top barriers of adoption [17] [72] [83] [146] [147] [155]. Effort in creating an ecosystem of partners includes defining use cases, setting standards, developing infrastructure and applications, and operating the blockchain network. Building a blockchain ecosystem requires considerable efforts to form the network including convincing healthcare providers to join [279].

Blockchain requires industry to develop strategic alliances and partnerships. Disintermediation entices industry collaboration and derives new business models. Disintermediation allows for eliminating nonvalue generating processes and intermediaries [43] [46] [48] [53] [71] [274].

The four social factors have been validated as important factors and weighted differently in their importance of adoption. Healthcare organizations need to understand their social dynamics and address them in order to have successful adoption.

9.4 Practical Application: Technical Perspective

In the technical perspective, four factors have been validated as important and quantified by the experts. These factors are: Infrastructure & Platform Integration, Standardization, Security and Privacy, and Blockchain Maturity & Use Cases. The technical factors quantification results show that Security and Privacy factor is the most important factor with relative importance of 34.7%. The second most important factor is the Standardization with relative importance of 22.6%. Infrastructure & Platform Integration and Blockchain Maturity & Use Cases were ranked the least with 21.3% for both.

Security and privacy are still foremost concerning in Blockchain-based healthcare [104] [277]. Due to the importance of data security and the strict regulatory rules on the security of patient health records, blockchain adoption is moving very slow. There are many security concerns surrounding blockchain that have to be addressed before it will be widely adopted in the healthcare industry. Healthcare organizations need to recognize security deficiencies in their current practices, as well as; the blockchain solution and its inherent security challenges.

EHR systems use different standards, which pose a problem for data exchange. Standardization requires implementation phase considerations. There is a lack of agreed-upon standards among vendors and clients in which most blockchain vendors do not offer compatible software. Effective collaboration between: regulators, technology providers, and healthcare organizations, is required to establish industry standards, and foster blockchain adoption [104] [274] [276] [280]. Healthcare organizations should undertake initiatives to encourage adoption and promote industry standards. Healthcare organizations need to have a clear strategy on what data, size, and format, can be sent to the blockchain.

Blockchain adoption may require significant changes to the existing legacy system. In order to make the change or switch, companies must strategize the transition phase. Blockchain technology should integrate seamlessly with other legacy systems [94] [278] [275] [277]. Healthcare organizations need to either procure or develop blockchain-based solutions. The solutions will need to interoperate with their present legacy systems or transform their existing systems to be blockchain compatible.

Blockchain is still maturing and growing. Maturity means that the technology has been used, tested, and the capabilities have been proven [18] [54] [73] [147] [275]. Maturity includes data and information of use cases, skills availability, and knowledge levels. The lack of real-world applications of blockchain technology, in managing and sharing patient records, hinders its widespread adoption. Surveys have shown that the immature state of the blockchain is a significant adoption barrier. Healthcare organization should improve their maturity in understanding the technology.

These four factors have been validated as important factors and weighted differently in their importance in the adoption. Security and Privacy was the top factor. Healthcare organizations need to understand their technical dynamics, and address them, in order to have successful blockchain adoption.

9.5 Practical Application: Organizational Perspective

In the organizational perspective, three factors have been validated as important and quantified by experts. These factors are: Management Support, Training and Skills, and HIT Strategy. The organizational factors quantification results show that the Management Support factor is the most important with relative importance of 43.4%. Management Support is considered one of the most important factors in the overall model. The second most important factor is HIT Strategy with relative weight of 35.9%, followed by the Training and Skills with relative importance of 21.1%.

Top management support is an essential cornerstone in the successful adoption of blockchain technology [278] [275]. There is a lack of blockchain technology understanding, and awareness, at the organizational level. Top management has shown reluctance to adopt the technology. Yet, the level of acceptance, and realization of benefits, of blockchain by top management is a required adoption factor.

It is essential to understand the role of blockchain technology adoption in achieving the higher-level strategic objectives of a healthcare organization. Blockchain should: help improve patient health care, increase patient engagement, enhance efficiency and cost reduction, improve quality of care and outcomes, and enhance care coordination.

Blockchain adoption should be in alignment with the healthcare organization's IT strategy [17] [21] [72] [105] [147].

There is a lack of in-house skills/understanding required to build and maintain the blockchain [275] [276] [278]. Healthcare organizations need to clearly define the skillset and training needed to implement and maintain blockchain initiatives. Skillsets and training include activities related to training internal staff and hiring technical specialists for the development of related blockchain and using their skills and competencies. The blockchain service providers are trying to address the gap "blockchain talents" in healthcare organizations through utilization of existing workforce, cross-training programs, and collaborations between private and public sectors.

The three factors have been validated as important factors and weighted differently in importance of adoption. Management Support factor was rated highest. Healthcare organizations should be able to understand their organizational dynamics and address them in order to have successful adoption.

9.6 Practical Application: Regulations & Legal Perspective

In the regulations & legal perspective, three factors have been validated as important, and quantified by experts. These factors are: Regulation Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. The regulations & legal factors quantification results show that the Regulation Compliance factor is the most important factor with relative importance of 37.3%. The second most important factor is Regulatory Uncertainty & Governance with relative importance of 33.4%, followed by Incentives Availability factor with 29.1%.

Regulation Compliance is ranked as the top overall factor. Regulation compliance involves the extent to which blockchain can comply with existing laws and regulations [17] [73] [80] [149] [155]. The diffusion and acceptance of blockchain technology relies mainly in the ability of the technology to comply with healthcare regulations and meet legal rules, such as data sharing, privacy, and security. Diffusion and acceptance also rely on blockchain technology being flexible in adapting to new regulations and policies.

Blockchain technology is an emerging and immature technology that is in the early stage of its lifecycle. Regulations around the technology are still uncertain [274] [279]. Regulatory bodies should consider collaboration with industry partners to facilitate adoption. The ability of healthcare organizations to work with partners to set up the rules that govern and administrate blockchain networks is a must. Partnerships, in response to the regulatory uncertainty, as well as the development of the technology itself is a must [94] [275].

Incentives availability to the adopters would encourage organizations to adopt blockchain and participate in data exchange [17] [83] [94]. Participation could be encouraged through financial incentives by offering programs similar to the Center for Medicare and Medicaid Services (CMS)'s Meaningful Use program. The Meaningful Use program incentivizes healthcare organizations to switch to electronic medical records.

These three factors have been validated as important and weighted differently in their importance of adoption. The Regulation Compliance factor is the highest rated factor. Healthcare organizations need to understand their regulatory dynamics and address them in order to have successful blockchain adoption.

CHAPTER 10: CONCLUSION

The final chapter of this research provides the research conclusion, suggests some insights from the case studies, discusses the research contributions, how the research gaps were addressed, and how this research could potentially help healthcare organizations improve success rates of blockchain adoption. The limitations of this research will be discussed, and opportunities for future research will be presented.

The uniqueness of this research is that it draws upon an extensive literature review in healthcare information: technologies, methodologies, and technology adoption resulted in identifying and quantifying adoption perspectives and factors. A complete view of the adoption problem is established via incorporation of multiple perspectives into a model which can be used for the benefit of healthcare organizations, the blockchain industry, and policymakers.

The main objective of this research is to identify the important factors and assess their impact on the blockchain technology adoption. The framework can be used by healthcare organizations to assess their readiness for blockchain adoption to improve their success rate. Blockchain projects have shown high rate of failure. Many projects fail to deliver their intended objectives, resulting in shutting down or scaling back. There is a lack of research studies that comprehensively investigate factors impacting blockchain adoption. The lack of research includes the lack of frameworks that will improve the successful blockchain adoption rates. The proposed model has developed a scoring model to evaluate the healthcare organization’s readiness to adopt blockchain technology. The scoring model looks at adoption from multiple perspective (financial, social, technical, organizational, and regulations & legal) which allows healthcare organizations and decision makers to have a broad range look into the adoption.

10.1 Case Studies' Insights

This section sheds some light on insights revealed from case studies, such as:

- Two cases from different healthcare systems present their unique characteristics and how they interact in the adoption of emerging technologies such as the blockchain.
- The two cases confirmed that the model provided an effective and practical assessment of their readiness for blockchain adoption.
- Case 1 scored/performed better in the technical and regulations & legal perspectives. These two perspectives were ranked the highest perspectives in the general model.
- Case 2 scored/performed better than Case 1 in the financial, social, and organizational perspectives.
- Regulations & Legal: Case 1 has strong expertise in addressing technologies and compliance whereas Case 2 has flexible and cooperative regulation landscape.
- Mature technical capabilities in Case 1 vs developing technical capabilities in Case 2.
- Financial resource and support due to government initiative toward digitalization in Case 2 vs proven ROI and financial measurements in place for Case 1.
- The social aspect is moving forward slowly. (In Case 1, high importance in the established connection, partnerships, and the current ecosystem)

- The organizational aspect is addressed equally. (Case 2 has more management support toward digitization and technology adoption while Case 1 offers better and frequent training).

The following Table 69 present a comparison between the two cases with regards to their performance at the perspective level in the assessment.

Table 73. Cases comparison at the model perspectives

Perspectives	Case 1	Case 2
Financial Perspective	11.76	13.32
Social Perspective	6.35	6.86
Technical Perspective	16.42	12.04
Organizational Perspective	12.29	12.97
Regulations & legal Perspective	20.20	18.69
Readiness Scores	**67.03**	**63.88**

10.2 Recommendations

This section provides recommendations to blockchain adopters. These recommendations are divided into two sets. The first set is based on the factors believed to be most important in blockchain adoption based upon their ranking (according to the experts). The second set of recommendations are based on factors where the two case studies scored low.

10.2.1 Recommendations based on Factors Weights

Experts were asked to rank factors based on importance. The dynamics of each factor was determined, and the healthcare organizations status resulted. The desirability curves determined the different levels for each factor ranking from the least optimal; to the most optimal. The recommendations are based on the most optimal level. Healthcare organizations should strive to reach most optimal level for each important factor to achieve a high level of readiness for the blockchain adoption. Table 70 shows the recommendations based on the factors' weights.

Table 74. Recommendations based on Factors' Weights

Factors	Recommendation	Reference
Regulation Compliance	Healthcare organizations should be able to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with blockchain technology such as HIPAA, PHI, data sharing, and technological laws in order to satisfy the compliance aspect, preserve data privacy. and adherence to privacy regulations.	[17] [73] [80] [149] [155]
Regulatory Uncertainty & Governance	Healthcare organizations should have advanced (documented, updated, and audited regularly) governance strategy. It involved clarity and maturity on the consensus mechanism, access control, smart contracts, the rules that administrate the blockchain network, what data to be stored on-chain and off-chain as well as the flexibility to adapt to and address new changes in the regulatory landscape.	[80] [84] [140] [146] [160] [94] [274] [275] [279]
Budget Availability	Healthcare organizations should be committed to providing the needed financial resources for the execution and long-term support commitment.	[80] [83] [105] [146] [147] [94] [274] [277]
Financial Risk and Uncertainty	Healthcare organizations should conduct risk assessments and anticipate various financial costs associated with getting Blockchain to work, such as expanding the Blockchain network, cost of transactions, maintenance, and scalability.	[17] [80] [83] [148] [146] [147] [278]
Security and privacy	Healthcare organizations should have the ability to identify and foresee the areas of deficiency related to system security and technical features of the current practices and the Blockchain solution in order to prevent any malicious access to healthcare information by unauthorized entities.	[46] [63] [71] [104] [146] [147] [104] [277]
Management Support	It is very important to have a high level of support, engagement, and approval of the top management to the blockchain initiative.	[73] [81] [105] [147] [150] [278] [278]

10.2.2 Recommendations based on Case Studies

The model has been applied to two case studies in testing readiness level. the following set of recommendations are based on the areas where two healthcare organizations have scored lowest. This points to where healthcare organizations may be weak and what needs to be done to address the weaknesses. Table 71 shows the recommendations based on the two case studies.

Table 75. Recommendations based on Case Studies

Factors	Recommendation	Reference
Budget Availability	Healthcare organizations should be committed to providing the needed financial resources for the execution and long-term support commitment	[80] [83] [105] [146] [147] [94] [274] [275] [276] [277]
Blockchain Ecosystem	Healthcare organizations should put more efforts in working with partners to build an active blockchain ecosystem that includes creating an environment of shared value, defining use cases, developing infrastructure and applications, operating the blockchain network, and solving any additional obstacles.	[17] [69] [72] [83] [146] [279]
Blockchain Maturity & Use Cases	This involves the activities and efforts of the healthcare organizations to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects. The activities that ensure the maturity of the technology understanding involves the understanding of the need for blockchain, translate it in technical requirements and develop it while keeping the product owner well informed, a specialized team with business experts, concept designers and development team specialized in blockchain is highly required.	[18] [54] [73] [147] [275]
Talent & Knowledge Acquisition	Healthcare organizations should have the capabilities and performance to identify, access, and acquire external knowledge and talents needed for the development of the blockchain solution for both foundational platform programming and blockchain application development	[73] [147] [149] [150] [152] [153] [154]
Standardization	Healthcare organizations should be clear on what data, size, and format can be sent to the blockchain as well as agree on common terms, business logic, and business flow as they share access to the same data and apply the same smart contract enabled business logic.	[54] [80] [101] [144] [148] [146] [147] [274]

		[104] [280] [276]

10.3 Contributions

By accomplishing the research objective, the following contributions are expected:

10.3.1 Theoretical contributions

At the academic level, this research contributes to the technology management body of knowledge on the assessment of emerging technology, blockchain, in healthcare using a robust decision-making model, specifically HDM. The definitions of the HDM perspectives and factors, through the expert's judgment quantification, show the robust capabilities of the hierarchical decision modeling in healthcare. This research aims to increase knowledge of how healthcare organizations assess the implementation and adoption of blockchain technology, for the management of the EHR, by proposing a technology management assessment tool.

This research gives insights into reasons behind the slow adoption and failure of many blockchain adoption projects. As the literature review and the gap analysis sections of this proposal indicate, there is a lack of structured, and comprehensive, understanding of different perspectives around blockchain adoption in healthcare, including: organizational, technical, social, financial, and personal perspectives. This model helps identify the highest rated factors that need to be considered during the implementation and adoption processes.

This research advances healthcare organizations' understanding and highlights the factors impacting the adoption of blockchain technology, in the management of the EHR systems. This scoring model reduces the failure rate of blockchain adoption by providing early indicators, for which perspectives or factors need more attention, before or during the implementation or adoption of blockchain solutions. This research addresses the need for a model to facilitate adoption of blockchain technology, for the management of her, with the objective to improve health organizations success rates.

The theoretical contributions of this research to the Technology Management academic literature are described below:

1- This research contributes to the Technology Management body of knowledge on the assessment of emerging technology, blockchain, in healthcare using a holistic and robust decision-making model, specifically HDM.
2- The proposed framework will potentially be the first study that proposes a comprehensive investigation of the blockchain adoption that includes the essential factors impacting the blockchain adoption and assessing their weights in the healthcare context. It was observed that there was no holistic assessment framework, and this research advances the research of the perspectives and factors central in health technology adoption assessment.
3- A complete view of the adoption problem has been established through incorporation of multiple perspectives, into the base model, for the benefit of: healthcare organizations, blockchain service providers, and policymakers. The model will provide knowledge for decision-makers concerning five perspectives: financial,

social, organizational, technical, and legal & regulatory. These variables were identified as important based on the literature review and the validation of the experts that influence the adoption process and will drive adoption

4- This research uses the hierarchical decision model (HDM) as an assessment system using both quantitative and qualitative metrics. The holistic study will be validated using: content, construct, and criterion-related validation methods. It will contribute to the literature by expanding the use of new, to the discussion topic, research methodology, HDM. Previous research is limited to a few traditional research methods, such as: material review, discussion, statistical analysis, etc.

Other contributions that this research achieves, includes:

1. Successful implementation of blockchain technology means more interoperable systems. Interoperability results in: cost savings, reduced waste, and better-quality care. The outcomes of the research grow the contribution of Technology Management in the healthcare industry and may be applied in different sectors.
2. The literature on adoption of blockchain in healthcare, and more specifically the healthcare organizations' readiness, is missing. This research contributes to the academic literature by updating the literature on Health IT (HIT), based on the emergence of blockchain and its promising benefits.
3. This research enables better quality assessment of blockchain adoption. Blockchain is an emerging technology. An accurate understanding of interactions between blockchain and its application in healthcare is assessed. The adoption scoring model provides a tool for technology assessment in healthcare.

10.3.2 Contribution to the industry

The healthcare sector is heavily regulated. Disruption is rare due to healthcare's unique characteristics. Larger HIT project sizes involve: multiple parties, healthcare partners, regulators, and insurers. Larger HIT project sizes have higher complexity.

The current state of blockchain projects is reporting a high rate of failure. There is a wide range of significant risks that exist, such as: blockchain immaturity technology, regulation uncertainty, and public acceptance. Studies show that the current blockchain projects are limited to: white-papers, proof of concepts, and products with a limited user base [17]. Blockchain projects are: immature, can be challenging to scale, poorly understood, and unproven in mission-critical [18] environments. A high number of blockchain projects are either shutting down or scaling back. Objectives and timeline are affected by project failure. 90% of these blockchain projects will not survive to be operational [22].

The problem with blockchain adoption is educational and organizational rather than technical [20] [21]. Forrester tracked 43 blockchain projects in multiple industries and concluded that none of the projects had achieved their full implementation objectives [23]. According to the VP of the Forrester, "In 2018, we expect to see a number of projects stopped that should never have been started in the first place." [24]. Adoption and implementation of blockchain technology involves changes in the healthcare organization's: culture, infrastructure, and how organizations conduct business. Environmental changes are large undertakings that require resources where failure is costly to the bottom line.

Blockchain adoption projects have been struggling to succeed. A mechanism that facilitates assessment of healthcare organizations' readiness, for such transformation adoption, is required in order to identify the most important factors impacting success. The assessment measures readiness to adopt blockchain, and points to where corrective actions are needed to the plan.

Practical contributions of this research, to the industry, include proposing a model that will improve the chances of successful blockchain adoption. This research provides a framework for healthcare organizations to use to facilitate and understand factors impacting adoption of blockchain technology, in the management of the EHR systems.

This research introduces an effective mechanism to assess the adoption of blockchain technology through identification of challenges, and considerations to facilitate the adoption of blockchain, and ensure successful implementation. A best understanding of internal and external factors that might undermine adoption and implementation of blockchain, as well as; undertaking preventive measurements to those challenges and considerations will make the adoption successful. In the analysis of Factors and their contribution to blockchain technology is the key to analyzing adoption in healthcare.

This research helps healthcare organizations achieve a better understanding of blockchain, including: where they are in dealing with the adoption process, where they need to be, and the challenges surrounding the adoption. The model provides a tool for evaluation of blockchain technology adoption that will improve clinician satisfaction and quality of care. This model may be used in different stages of adoption. It may be used before starting implementation and during. It is able to gauge the organizations ability to move forward with an adoption project.

At a functional level this research:

1. Introduces an effective mechanism to assess adoption of blockchain technology, through identification of challenges and considerations that need to be addressed. The assessment facilitates the adoption of blockchain and ensures successful implementation. The assessment results in a higher understanding of various internal and external factors that undermine adoption and implementation of blockchain. The assessment lends preventive measurements to adoption challenges and considerations in order to make sure the adoption is successful.
2. The question about the blockchain is not: "Does the technology work? Yes, it does.", the current question is, "How can it be adopted?". There is not enough knowledge, in the healthcare blockchain body of knowledge, on how healthcare organizations may adopt and assess their readiness level. This research provides a framework that can be used by healthcare organizations to assess their readiness for blockchain technology adoption and prepare for technology implementation at different stages, before or during, the project. The literature shows a high blockchain projects failure rate.
3. Aids decision-makers in healthcare classification and organization of priorities and supports their decision-maker judgment as to where they are as an organization now, and where they need to be in order to adopt and implement blockchain technology successfully. The scoring model provides an effective tool to measure their blockchain technology adoption.

4. Enables healthcare organizations to look at the adoption problem comprehensively from multiple perspectives considering internal and external factors in order to identify, and comprehend, the most important factors for blockchain adoption. Learning which factors are significant may lead to better incentives, and programs, for organizations, helping them to overcome barriers in their healthcare technology implementations.
5. Encourages healthcare organizations and regulators to move forward with blockchain projects while ensuring successful implementation.
6. This research will promote more blockchain successful adoption. It will: reduce the fear of patients regarding their health data privacy, encourage regulators to consider compliance with regulations and rules as an important factor, and provide insights to healthcare organizations regarding the current blockchain failure rate.

Additional research contributions:

1. This model could be used to: help healthcare organizations assess their readiness for adoption, help blockchain alliances aim at forming a blockchain network by assessing their members' readiness for blockchain adoption, and help existing alliances and networks adding new organizations to their previously established blockchain network. The model ensures readiness, which as a result, improves the chance of a successful adoption.
2. This model generalizable and can be applied in different industries. The model has been validated through content, construct and criterion-related validity which ensures

the generalizability for use in different healthcare scenarios and industries. The experts were asked to provide their feedback regarding the acceptability of the results and the generalizability of the model. This research considered the application of blockchain in healthcare as a focused area. Blockchain applications are vast, with differences across sectors.

3. This research encouraged healthcare organizations to plan and design their health information technology infrastructure, incorporating blockchain and new disruptive technologies.
4. This research approach integrated sensitivity analysis into the assessment model in order to provide decision-makers additional insights, enabling better decision-making. Sensitivity is important because business environments change, technology changes, and regulations mature.
5. Current adoption rate failure is high. This research identifies the most important adoption drivers and attempts to reduce the failure rate by paying most attention to essential success factors, before and during adoption.

10.3.3 Contribution to MCDM

Section 5.4 provides a review of essential MCDM tools, such as: TOPSIS, PROMETHEE, AHP, ANP, HDM, ELECTRE, and MAUT. The review of these tools included the tools' background, strengths, and weaknesses. The research on blockchain technology adoption using MCDM tools is observed to be: very limited, and does not adequately address adoption issues. Section 5.4 provides selected literature on the

MCDM tools that have been used to investigate blockchain. The existing research has been limited to a few traditional research methods such as: material review, discussion, etc. Thus, this research has potential to contribute to the multi-criteria decision-making research by increasing the utilization of MCDM tools, in order to examine the complex problem of the blockchain technology adoption. Blockchain is as an emerging technology in the healthcare. The proposed MCDM model in this research assists decision-makers by identifying and ranking the most important factors on the blockchain adoption and provides a scoring model to help healthcare organizations understand where they are in adoption maturity and capabilities and where they need to move to be successful.

10.3.4 Contribution to HDM

This research uses Hierarchical Decision Making (HDM). HDM is an MCDM tool that breaks down complex problems into smaller more manageable tasks for analysis. HDM allows for a comprehensive view of the decision and looks into it from multiple perspectives. HDM incorporates expert judgments into the decision model for a higher-level understanding of important factors for decision-makers and experts in the healthcare industry. HDM is a flexible tool that combines qualitative and quantitative data. The HDM model has the ability to assess individual and group rankings of perspectives and factors for higher level analysis.

The following is a summary of how this research that advances the HDM approach:

1. This study, is the first study that, uses HDM to comprehensively investigate assessment of blockchain technology in healthcare. This study advances the research,

of the perspectives and factors, central in health technology adoption assessment. This study enables solutions, of similar problems, in health care settings using an expert judgment tool. Similar studies include the research done by: Hogaboam [188] that assess the technology adoption potential of medical devices: case of wearable sensor products for pervasive care in neurosurgery and orthopedics; and the work done by Alanazi et al. [282] that identify the best alternatives to help the diffusion of teleconsultation by using the Hierarchical Decision Model (HDM).

2. This research expands the use of HDM in assessing blockchain in healthcare, and validates the capabilities of HDM to be able to break down the complex problems of blockchain adoption in healthcare.
3. The model is an addition to the HDM methodology and represents a genuine application. This model is focused on the use of HDM for assessment of blockchain in healthcare. It does not develop new theory, but it is an application of HDM (which has been proven effective in diverse applications). This study continues to prove the capabilities of the HDM tool in a healthcare setting.

10.3.5 Research Gaps and Outputs

This research resulted in a model that can be used by healthcare organizations to assess their readiness to adopt blockchain. The research draws upon an extensive literature of the current publications, and expert feedback to address the gaps and answer the research questions. The HDM methodology was used as a methodology to build a hierarchical presentation of the extracted and validated factors, and to elicit experts' judgment to identify the relative importance of each factor. A case study was conducted. Two healthcare organizations were assessed using this study's model to demonstrate the model's practicality and effectiveness in evaluating readiness for the blockchain adoption. The following two tables present summaries of how the research addressed the gaps, and how the research outputs were answered.

Table 76. Summary of the research gaps and the research contributions

Research Gaps	Contributions
There is a lack of Multi-criteria holistic studies to assess the blockchain adoption.	The HDM model proposed by this research is a comprehensive and developed in a structured way to evaluate readiness assessment for a blockchain adoption.
There is a lack of studies that assess the adoption of blockchain in a comprehensive way.	
There is a lack of studies that highlights the internal and external factors impacting the healthcare organization's readiness for blockchain adoption.	This research is based on a comprehensive review of the current literature and the incorporation of expert's judgment. The research identified the most important factors influencing blockchain adoption projects and what are their relative importance/priorities. Also, factors are classifying into perspectives.
There is a lack of studies that quantify the expert judgments and present the importance level of the factors and perspectives considered in the assessment.	
There is a need to update the literature related to Health IT and EHR based on the emergence of blockchain and its promising benefits.	This research contributes to the Health IT and blockchain by developing a readiness assessment tool in healthcare using a robust decision-making model tool, specifically HDM.

Table 77. summary of the research outputs and the research contributions

Research Outputs	Research Contributions
Identification of the perspectives and factors for assessing the healthcare organization's readiness for blockchain adoption	This research is built upon a comprehensive review of the current literature as well as incorporating inputs from subject matter experts.
Identification of the relative importance of each perspective and factor in the assessment process	The research identified the most important factors influencing blockchain adoption and then incorporate expert's judgements to identify their relative importance/priorities.
Provide a tool for healthcare organizations to assess their readiness for the blockchain adoption for EHR in order to overcome challenges with the existing healthcare system	This research proposed a robust decision-making model tool, specifically HDM, to assess healthcare organization's readiness for blockchain adoption.
Highlight the disagreement level among experts from different fields and backgrounds on the relative importance of the assessment factors	The disagreement level among the experts have been shown to be within the acceptable level. experts were invited to participate holds wide range of expertise and have different exposure to the topic. (see chapter 6)
Examine the effectiveness and practicality of the model for assessing the adoption of the blockchain technology for the management of the EHR by healthcare organizations	This model was applied at two healthcare organizations as case studies for the study and has proven its capability to assess their readiness (See Chapter 7)

10.4 Limitations

The results of this research are context and time dependent. At any time in the future the: Financial, Social, Organizational, Technical, and Regulations & Legal factors may not be in the same state, as at the time of this study. The model was applied at two healthcare organizations. Two cases, from two countries, with different healthcare systems lends value to the generalizability of the model. More cases would increase its robustness and improve the claim of generalizability by improving confidence of generalizability. This model has been built with healthcare in mind which could limit its generalizability to other sectors. This model may be used with minor tailored changes to the weighted factors based on relative importance with respect to intended application and context. The current state of the blockchain is: s immature technology, and immature projects. As the technology develops and matures, the weights will change. Once concern is that the HDM model may lack flexibility as these conditions change.

The generalizability of the results derived from the research is context and time dependent. The financial, organizational, social, technical, and regulatory factors may not be the same as it is currently. Sensitivity analysis shows how robust and flexible the model is to such changes. The pairwise comparison may need to be redone if a change is observed in factors with high sensitivity.

There is some limitation related to the expert's judgement. HDM relies heavily on the expert's judgments, which can present some challenges. Experts who participated in this research were selected carefully using various methods and tools (see chapter 5). Still, Experts are humans, and their judgments will be affected by biases and judgment making. It is hard to reach a significant level of objective judgment. This research tried minimizing biases by conducting proper procedures in selection of expert panels and results analysis.

10.5 Future Research

There are many opportunities for future research, such as: results from the research findings being further analyzed, or discussion with the experts being tailored. The limitations of this research present opportunity for future research. New factors can be added to this model as blockchain technology continues to develop, and as the number of adoption cases increases. Blockchain adoption has had significant progress in various sectors and industries. There is potential to conduct more instances of this research using and applying this same model. This model could be applied to: other healthcare organization, different use cases, and in different healthcare systems. Expert judgments could be re-incorporated, in order to keep the model relevant and up to date. Some other research suggestions include: investigating the role of government support, as well as; investigating the interaction between healthcare organizations and regulators to foster successful adoption. Overall, the strategic approach of healthcare organizations toward blockchain is an appealing area of research.

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APPENDICES

Appendix A: LETTERS OF INVITATION TO EXPERTS

Recruiting Letter:
Title: Invitation to Participate in my Ph.D. Research as a Subject Matter Expert
Hi [First Name],
How are you?

I'm a Ph.D. student at Portland State University (the Engineering and Technology Management department) etm.pdx.edu.

I'm researching the blockchain technology adoption for the management of the EHR systems.

As part of my research, I'm developing a model that can be used by healthcare organizations to assess readiness to adopt blockchain, and I need subject-matter experts to validate and quantify my research model.

As an expert, your anonymous input is valuable for my research. I would be grateful if you can help me by participating in my research.

Participation:
Here is what is needed, should you accept to participate:
First round:
Survey – 10-15 minutes: Validating the most important factors affecting the blockchain adoption in healthcare.
Second round:
Survey – 10-15 minutes: Ranking the factors.

I appreciate your help and time.

Consent
Your participation in this study indicates that you have read the information provided on this link:
https://drive.google.com/file/d/1hDhWGEUwt573gfp70tMekWQuEkzkDTPb/view?usp=sharing

The consent form indicates that you are not waiving any of your legal rights as a research participant, your personal information will be confidential and will not be shared with any third party, and you can withdraw from participating at any time.

Best Regards,

Saeed

Invitation to Validate the Model Letter:
Title: [Research Survey]: Validating the Model Survey

Dear [First Name],

Thanks for accepting my invitation to participate in my research.
The first step is to evaluate the factors affecting a successful Blockchain adoption in Healthcare.

Attached to this email you will find a summary about my research, please go through it then do the survey on the below link:
Survey link:
https://portlandstate.qualtrics.com/jfe/form/SV_3x8G5p7cHGlI5Lf

Duration: The survey should not take you more than 10-15 minutes to complete.
Deadline: I'll appreciate it if you can do the survey at your earliest convenience.
If you have any questions, please don't hesitate to contact me.

Consent:
Your participation in this study indicates that you have read the information provided (or the information was read to you) on this link:
https://drive.google.com/file/d/1hDhWGEUwt573gfp70tMekWQuEkzkDTPb/view?usp=sharing

The consent form indicates that you are not waiving any of your legal rights as a research participant, your personal information will be confidential and will not be shared with any third party, and you can withdraw from participating at any time.

Best Regards,
Saeed

Invitation to Quantify the Model Letter:
Title: [Research Survey]: Quantifying the Model Survey

Dear [First Name],

Thanks for accepting my invitation to participate in my research.
You are asked to evaluate the factors affecting a successful Blockchain adoption in Healthcare.

Attached to this email you will find a summary about my research, please go through it then do the survey on the below link:
Survey link:
https://portlandstate.qualtrics.com/jfe/form/SV_0pMuxcUzLKMLG17

Duration: The survey should not take you more than 10-15 minutes to complete.
Deadline: I'll appreciate it if you can do the survey at your earliest convenience.
If you have any questions, please don't hesitate to contact me.

Consent:
Your participation in this study indicates that you have read the information provided (or the information was read to you) on this link:
https://drive.google.com/file/d/1hDhWGEUwt573gfp70tMekWQuEkzkDTPb/view?usp=sharing

The consent form indicates that you are not waiving any of your legal rights as a research participant, your personal information will be confidential and will not be shared with any third party, and you can withdraw from participating at any time.

Best Regards,
Saeed

Appendix B: QUALTRICS SURVEY TO VALIDATE THE MODEL (Qualtrics Survey)

https://portlandstate.qualtrics.com/jfe/form/SV_3x8G5p7cHGlI5Lf

ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Saeed Alzahrani's Research Model Evaluation

Assessment of the Blockchain Technology Adoption for the Management of the EHR systems.

The goal of my research is to develop a model that can be used by healthcare organizations to assess their readiness for the Blockchain technology adoption and improve the success rate of the Blockchain projects by:
- Assess their readiness for the Blockchain adoption.
- Pinpoint areas where improvements need to be done before initiating such project.

Thank you for participating as an expert in my research.

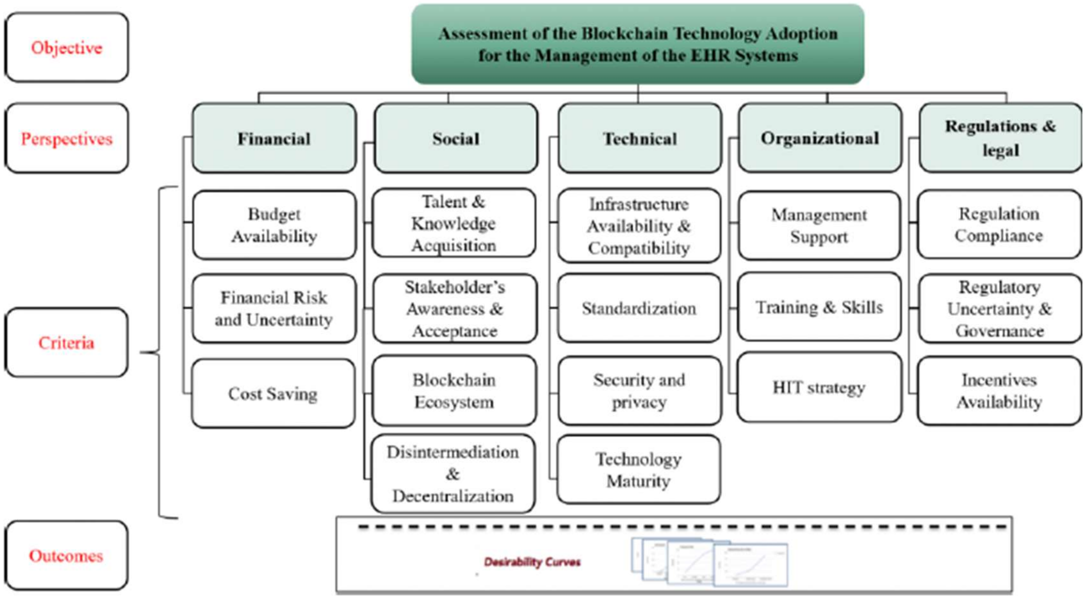
Research focus:
Before starting the Blockchain project, the healthcare organization is to use the model I'm proposing to assess if they are ready to do the project and test their capabilities, by comparing the healthcare organization's current status against a set of critical factors that are known to affect this kind of projects.

Survey Objective:
The objective of this survey is to validate the preliminary list of factors that were identified based on a comprehensive literature review. The following questions are intended to capture your judgment of the suitability of those factors and to identify those that might have gone undetected during my literature review. Your input will be used to help finalize my model.

Experts Validation:
In the next pages, you will be asked, to evaluate the factors identified by the research as the most critical factors impacting the Blockchain adoption (with focus on the application of the Blockchain for the management of the EHR systems). You will also be able to suggest other factors based on your experience. Your inputs and validation of the model ensures that the model is as practical and close to reality as possible.

Consent: I have had the chance to read and think about the information in this form. I have asked any questions I have, and I can make a decision about my participation. I understand that I can ask additional questions anytime while I take part in the research.

If you agree to the information in the consent form and take part of this study, please proceed to fill out the survey.



For the next pages of this survey:

Please click "Yes" if you think that the specific perspective/factor has an impact on the adoption of the Blockchain technology for the management of the EHR systems.

Please click "No" if you think that the specific perspective/factor has no impact on the adoption of the Blockchain technology for the management of the EHR systems.

If there are other criteria or if you have any comment, please add them in the space provided.

Block 1

Please enter your name:

First Name:

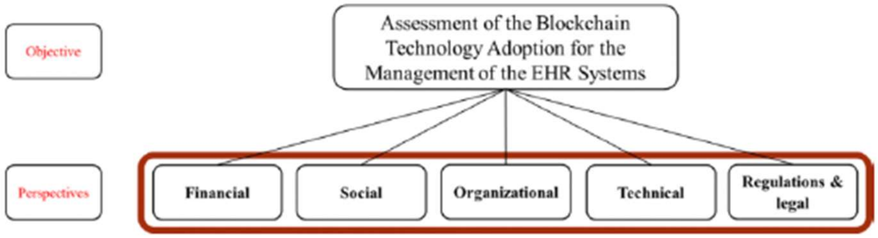
Last Name:

Saeed Alzahrani PhD research - Model Evaluation

First step is to validate the perspectives (classifications) of the factors affecting Blockchain adoption for the management of the EHR systems.

Please evaluate the perspectives considering the factors under each perspective (each perspective consists of a set of factors under it).

If you think the specific perspective and the factors under it have no impact on the Blockchain adoption, then click No. You will have a chance on the following pages to validate each factor under each perspective separately.



Perspective	Details
Financial Perspective	This perspective captures the financial side of assessing Blockchain technology adoption in healthcare organizations. Topics such as Budget availability, Financial Risk and Uncertainty, and Cost-Saving fall under this category.
Social Perspective	This perspective includes topics such as Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Decentralization. The stakeholders can take the shape of patients, providers, policymakers, payers, and physicians. This perspective also includes the ability of healthcare organizations to attract and acquire skilled workers and talents. Healthcare organizations should be willing to operate in a decentralized nature as well.
Technical Perspective	The technical perspective involves the challenges that are unique to Blockchain projects due to the nature of the technology itself and its characteristics. This perspective covers topics such as Infrastructure Availability & Compatibility, Standardization, Security and privacy, and Technology Maturity.
Organizational Perspective	This perspective covers the organizational aspects such as Management Support, Training & Skills, and alignment with HIT strategy. What needs to be considered by management to enable successful and sustainable Blockchain adoption within the healthcare organizations and overcome adoption barriers.
Legal Perspective	This perspective includes regulatory and legal aspects needed to assess the Blockchain adoption in healthcare such as Regulation Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. It involves interaction with external environment issues and entities.

Please identify the perspectives that you believe have an impact on the adoption of the Blockchain technology for the management of the EHR systems:

	Yes	No
Financial Perspective	○	○
Social Perspective	○	○
Technical Perspective	○	○
Organizational Perspective	○	○
Regulations & Legal Perspective	○	○

If you think that there are other perspectives or you have comments on the listed perspectives, please provide it here.

Block 6

Saeed Alzahrani PhD research - Model Evaluation

Second step is to evaluate the factors under each perspective that have impact on Blockchain adoption for the management of the EHR systems.

Financial Perspective	
Budget Availability	This factor measures the ability of the healthcare organization to dedicate and provide sufficient funds for the Blockchain Project as well as the budget flexibility with the other associated costs such as initial and participation costs.
Financial Risk and Uncertainty	The number of Blockchain projects are limited, and it is hard to be certain of the costs associated with its development and operation. This factor measures the ability of the healthcare organization to anticipate and account for risks associated with financially getting Blockchain to work, such as expanding the Blockchain network, cost of transactions, maintenance, and scalability.
Cost Saving	Many healthcare organizations are waiting for proven and clear return on investment measurements to move on in adopting blockchain solutions and join Blockchain network. This factor measures the ability of the healthcare organizations to have cost-benefits analysis and determined financial saving goals generated from the implementation of the Blockchain by utilizing various measurements.

Please identify the criteria that you believe have an impact on the adoption of the Blockchain technology for the management of the EHR systems under the Financial Perspective:

	Yes	No
Budget Availability	○	○
Financial Risk and Uncertainty	○	○
Cost Saving	○	○

If there are other criteria or if you have any comment, please add them in the space provided.

Block 2

Saeed Alzahrani PhD research - Model Evaluation

Social Perspective	
Talent & Knowledge Acquisition	This factor measures the healthcare organization's ability to acquire external knowledge and talents needed for the development of the Blockchain solution for both foundational platform programming and Blockchain application development.
Stakeholder's Awareness & Acceptance	This factor measures the level of stakeholder's engagement, awareness, and acceptance of the Blockchain in terms of realizing its relevance, understanding its potential benefits, challenges, feasible use cases, and how it works.
Blockchain Ecosystem	This factor measures the effort of the healthcare organization to work with partners to build an active Blockchain ecosystem that includes defining use cases, setting standards, developing infrastructure and applications, and operating the Blockchain network.
Disintermediation & Decentralization	This factor measures the willingness of the healthcare organizations to operate in a decentralized peer to peer nature without central authority or intermediaries and allow an auto exchange of data through distributed ledger without a central authority.

Please identify the criteria that you believe have impact on the adoption of the Blockchain technology for the management of the EHR systems under the Social Perspective:

	Yes	No
Talent & Knowledge Acquisition	○	○
Stakeholder's Awareness & Acceptance	○	○
Blockchain Ecosystem	○	○
Disintermediation & Decentralization	○	○

If there are other criteria or if you have any comment, please add them in the space provided.

Technical Perspective	
Infrastructure Availability & compatibility	The Blockchain technology or even any other technology should be able to integrate seamlessly with the existing legacy systems. This factor measures the IT hardware and software infrastructure needed for the Blockchain implementation in order to have sufficient and integrateable infrastructure.
Standardization	This criterion measures the ability of the healthcare organization to implement governance to control and make it clear what data, size and format can be sent to the Blockchain as well as define what medical data is stored on or off the Blockchain.
Security and Privacy	This factor measures the ability of the healthcare organization to identify and foresee the areas of deficiency in the privacy and security of using Blockchain in order to prevent access to healthcare information by unauthorized entities and adherence to privacy regulations.
Blockchain Maturity	Blockchain maturity means that the technology has been used, tested, and the capabilities have been proven that includes use cases, skills availability, and knowledge. Various factors such as regulatory concerns, lack of industry standards, mainstream application deficiency all undermine the technology's innovative potential and create the illusion of an immature technology. This factor measures the activities and efforts of the healthcare organizations to understand, prove, and test the Blockchain technology through use cases, prototypes, and small projects.

Please identify the criteria that you believe have an impact on the adoption of the Blockchain technology for the management of the EHR systems under the <u>Technical perspective</u>:

	Yes	No
Infrastructure Availability & compatibility	○	○
Standardization	○	○
Security and Privacy	○	○
Blockchain Maturity	○	○

If there are other criteria or if you have any comment, please add them in the space provided.

Block 4

Saeed Alzahrani PhD research - Model Evaluation

Organizational Perspective	
Management Support	The top management support is an essential and a cornerstone in the successful adoption of Blockchain technology. This criterion evaluates the level of support, engagement, and approval of the top management to the Blockchain initiative.
Training and Skills	This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help current staff, technical specialists, and medical staff attain the required level of knowledge or skill related to Blockchain solution as well as expedite the learning process.
HIT Strategy	It is essential to understand the role of adopting Blockchain technology in achieving the higher-level strategic objectives of the healthcare organization and its HIT strategy. Blockchain adoption requires significant changes to the existing system in which companies must strategize the transition. This factor measures the alignment of the Blockchain solution with the healthcare organization's IT strategy and objective of achieving a higher quality of care.

Please identify the criteria that you believe have an impact on the adoption of the Blockchain technology for the management of the EHR systems under the <u>Organizational perspective</u>:

	Yes	No
Management Support	○	○
Training and Skills	○	○
HIT Strategy	○	○

If there are other criteria or if you have any comment, please add them in the space provided.

Block 5

Saeed Alzahrani PhD research - Model Evaluation

Regulations & Legal Perspective	
Regulation Compliance	This factor measures the healthcare organization's effort to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with Blockchain technology such as HIPPA, PHI, data sharing, and technological laws.
Regulatory Uncertainty & Governance	This factor examines the ability of the organization to work with partners and government officials to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the Blockchain network.
Incentives Availability	This factor investigates the maturity, flexibility, and efforts of the healthcare organization to work with the regulators to define a legal framework to operate accordingly and being able to collaborate with other partners to address the changes and updates within the technology itself and the regulatory landscape which is necessary to support sustainable Blockchain development and operation.

Please identify the criteria that you believe have impact on the adoption of the Blockchain technology for the management of the EHR systems under the Regulation & Legal perspective:

	Yes	No
Regulation Compliance	○	○
Regulatory Uncertainty & Governance	○	○
Incentives Availability	○	○

If there are other criteria or if you have any comment, please add them in the space provided.

Block 7

Submission Confirmation

Thank you so much for your time and participation!

Please check the following if you would like to: (optional)

- ☐ Participate in the quantification phase based on the validation phase you just completed
- ☐ Receive the results of this research (if checked, please enter your email address below)

By clicking on the " -->" button, your answers will be submitted.

Appendix C: QUALTRICS SURVEY TO QUANTIFY THE MODEL (Qualtrics Survey)

https://portlandstate.qualtrics.com/jfe/form/SV_0pMuxcUzLKMLG17

ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Saeed Alzahrani's Research Model Ranking

Assessment of the Blockchain Technology Adoption for the Management of the EHR systems.

The goal of my research is to develop a model that can be used by healthcare organizations to assess their readiness for the Blockchain technology adoption and improve the success rate of the Blockchain projects by:
- Assess their readiness for the Blockchain adoption.
- Identify the factors that impact the Blockchain adoption.
- Pinpoint areas where improvements need to be done before initiating such project.

Thank you for participating as an expert in my research.

Research focus:
Before starting the Blockchain project, the healthcare organization is to use the model I'm proposing to assess if they are ready to do the project and test their capabilities, by comparing the healthcare organization's current status against a set of critical factors that are known to affect this kind of projects.

Survey Objective:
The objective of this survey is to rank the factors that should be considered when assessing a healthcare organization's readiness to adopt Blockchain for the management of the EHR systems.

The survey is designed to capture your assessment of the relative importance of each factor in comparison with the other factors, in order to rank and identify their relative weights.

Consent: I have had the chance to read and think about the information in this form. I have asked any questions I have, and I can make a decision about my participation. I understand that I can ask additional questions anytime while I take part in the research.

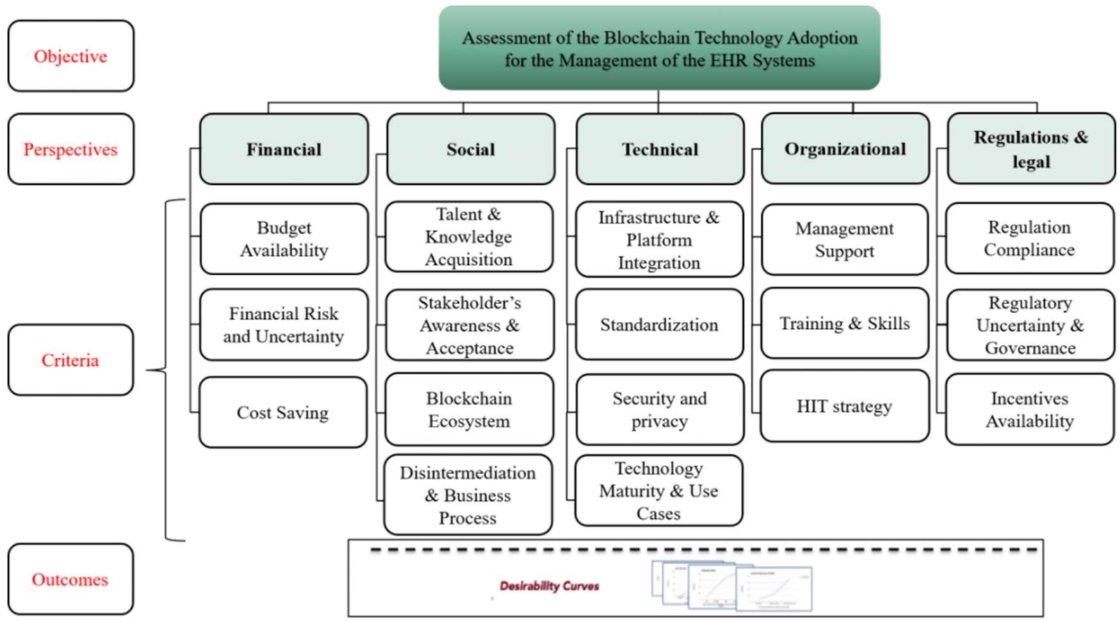
If you agree to the information in the consent form and take part in this study, please proceed to fill out the survey.

Please enter your name:

First Name:

Last Name:

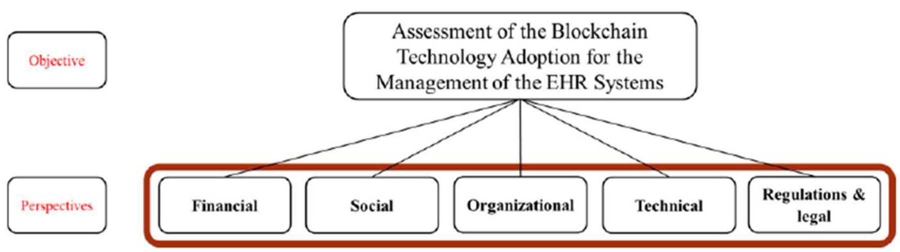
The Research Model:



Please click on the next button (-->) on the right bottom of the screen to start the survey.

llock 8

Saeed Alzahrani PhD research - Model Ranking



Perspective	Details
Financial Perspective	This perspective captures the financial side of assessing Blockchain technology adoption in healthcare organizations. Topics such as Budget availability, Financial Risk and Uncertainty, and Cost-Saving fall under this category.
Social Perspective	This perspective includes topics such as Talent & Knowledge Acquisition, Stakeholder's Awareness & Acceptance, Blockchain Ecosystem, and Disintermediation & Business Process.
Technical Perspective	The technical perspective involves the challenges that are unique to Blockchain projects due to the nature of the technology itself and its characteristics. This perspective covers topics such as Infrastructure & Platform Integration, Standardization, Security and privacy, and Technology Maturity and Use Cases.
Organizational Perspective	This perspective covers the organizational aspects such as Management Support, Training & Skills, and alignment with HIT strategy. What needs to be considered by management to enable successful and sustainable Blockchain adoption within the healthcare organizations and overcome adoption barriers.
Legal Perspective	This perspective includes regulatory and legal aspects needed to assess the Blockchain adoption in healthcare such as Regulation Compliance, Regulatory Uncertainty & Governance, and Incentives Availability. It involves interaction with external environment issues and entities.

You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: If A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for a summary about each perspective

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Financial Perspective												0
Social Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Financial Perspective												0
Technical Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Financial Perspective												0
Organizational Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Financial Perspective												0
Regulations & Legal Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Social Perspective												0
Technical Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Social Perspective												0
Organizational Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Social Perspective												0
Regulations & Legal Perspective												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Technical Perspective												0
Organizational Perspective												0
Total:												0

	0	10	20	30	40	50	60	70	80	90	100	
Technical Perspective												0
Regulations & Legal Perspective												0
Total:												0

Pairwise Comparison

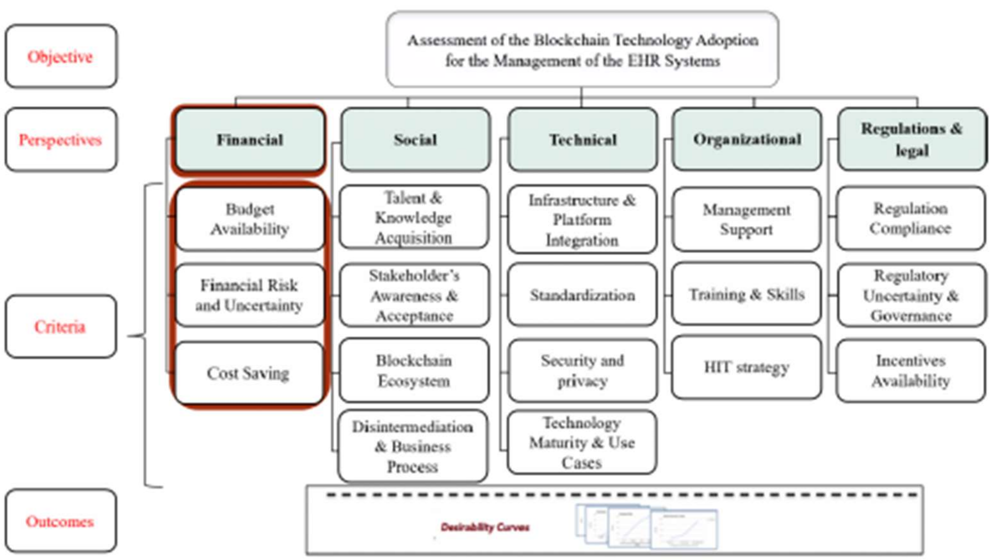
	0	10	20	30	40	50	60	70	80	90	100	
Organizational Perspective												0
Regulations & Legal Perspective												0
Total:												0

If you have comments, please provide them here:

Please click on the next button (-->) on the right bottom of the screen

Block 9

Saeed Alzahrani PhD research - Model Ranking



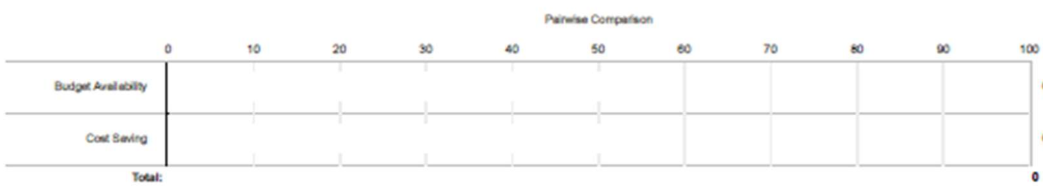
Financial Perspective	
Budget Availability	This factor measures the ability of the healthcare organization to dedicate and provide sufficient funds for the Blockchain project as well as the budget flexibility with the other associated costs such as operational, maintenance, and expansion.
Financial Risk and Uncertainty	The number of Blockchain projects are limited, and it is hard to be certain of the costs associated with its development and operation. This factor measures the ability of the healthcare organization to conduct risk assessments and anticipate various financial costs associated with getting Blockchain to work, such as expanding the Blockchain network, cost of transactions, maintenance, and scalability.
Cost Saving	Many healthcare organizations are waiting for proven and clear return on investment to move on in adopting blockchain solutions and join blockchain networks. ROI and cost reduction could come from the automation of intense human actions, elimination of unnecessary intermediaries or process, increased efficiency, reduce lag times (claims and clinical data), record duplication reduction, and data collection time and effort. This factor measures the ability of the healthcare organizations to have cost-benefits analysis and determined financial saving goals generated from the implementation of the blockchain by utilizing various measurements.

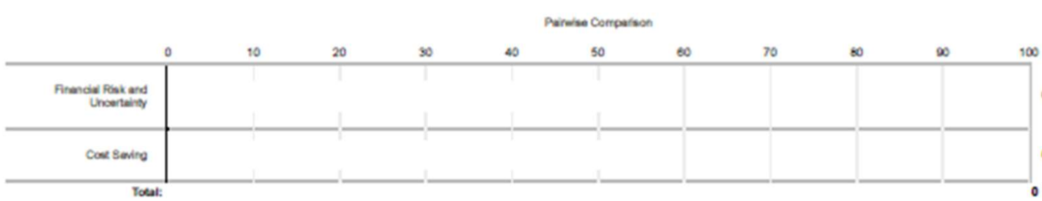
You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: If A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for a summary of each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.



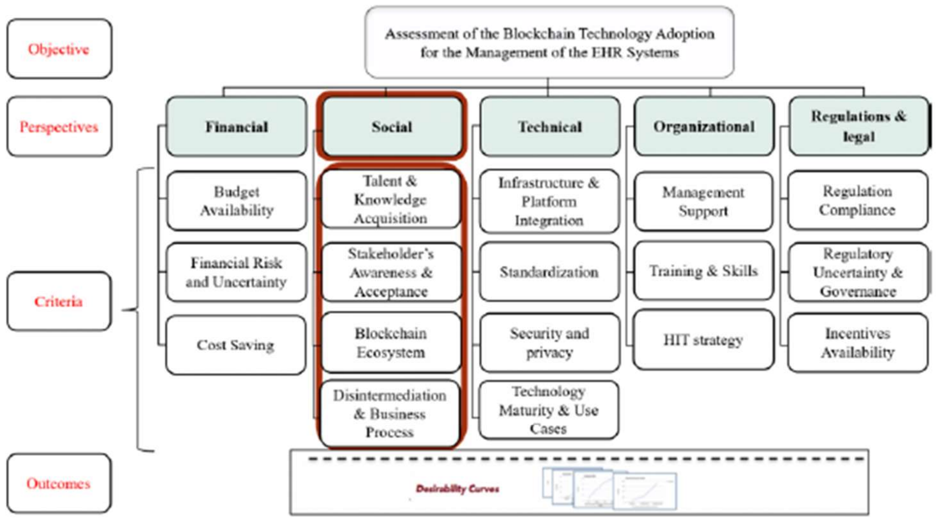


If you have comments, please provide them here:

Please click on the next button (-->) on the right bottom of the screen

Block 11

Saeed Alzahrani PhD research - Model Ranking



Social Perspective	
Talent & Knowledge Acquisition	This factor measures the healthcare organization's capabilities and performance to identify, access, acquire external knowledge and talents needed for the development of the Blockchain solution for both foundational platform programming and blockchain application development whether the solution is developed in-house or outsourced.
Stakeholder's Awareness & Acceptance	This factor measures the level of stakeholder's engagement, awareness, and acceptance of the Blockchain in terms of adequate realization of its relevance, understanding its potential benefits and challenges, and its existence and impact on the organization's health information technology.
Blockchain Ecosystem	This factor measures the effort of the healthcare organization to work with partners to build an active Blockchain ecosystem that includes creating an environment of shared value, defining use cases, developing infrastructure and applications, operating the Blockchain network, and solving any additional obstacles.
Disintermediation & Business process	This factor measures the willingness of the healthcare organizations to adopt new business process by allowing an auto exchange of data through distributed ledger and eliminating nonvalue generating processes or entities.

You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for summary about each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Talent & Knowledge Acquisition												0
Stakeholder's Awareness & Acceptance												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Talent & Knowledge Acquisition												0
Blockchain Ecosystem												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Talent & Knowledge Acquisition												0
Disintermediation & Business process												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Stakeholder's Awareness & Acceptance												0
Blockchain Ecosystem												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Stakeholder's Awareness & Acceptance												0
Disintermediation & Business process												0
Total:												0

Pairwise Comparison

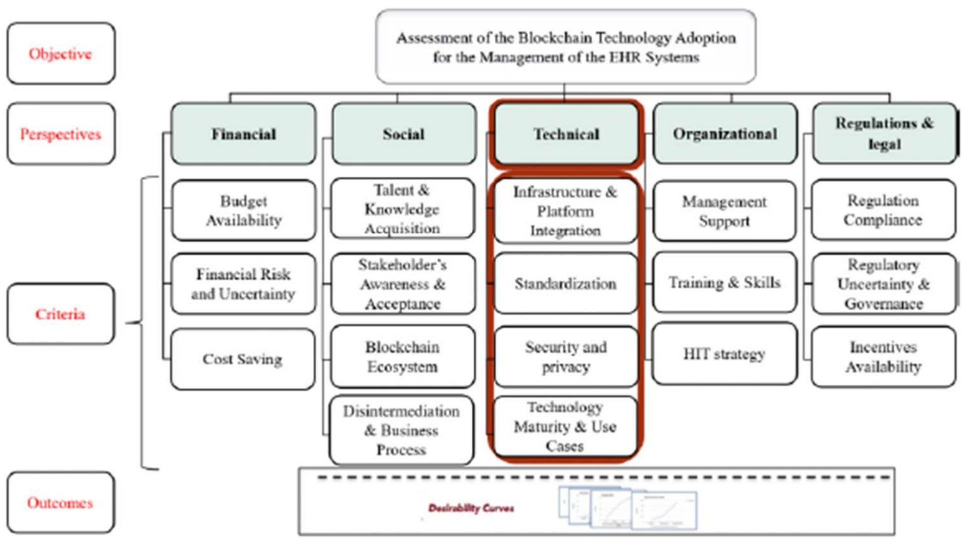
	0	10	20	30	40	50	60	70	80	90	100	
Blockchain Ecosystem												0
Disintermediation & Business process												0
Total:												0

If you have comments, please provide them here:

Please click on the next button (-->) on the right bottom of the screen

Block 12

Saeed Alzahrani PhD research - Model Ranking



Technical Perspective	
Infrastructure & Platform Integration	The Blockchain technology or even any other technology should be able to integrate seamlessly with the existing legacy systems. The healthcare organization should have sufficient and integrateable infrastructure in terms of hardware and software to support the implementation. This factor measures the integrability of the blockchain platform into the current infrastructure seamlessly.
Standardization	This factor measures the ability of the healthcare organization to be clear on what data, size and format can be sent to the blockchain as well as agree on common terms, business logic and business flow as they share access to the same data and apply the same smart contract-enabled business logic. Also, healthcare organization should have the willingness and flexibility to collaborate to further develop and recognize standard-setting body to progress Blockchain related standards as well as work with blockchain vendors to offer compatible software.
Security and Privacy	This factor measures the ability of the healthcare organization to mitigate privacy risks, how to use Blockchain to improve privacy, discover to what extent Blockchain provides security, manage new security risks, and identify the areas of deficiency in the privacy and security of using Blockchain for the management of the EHR in order to prevent access to healthcare information by unauthorized entities that can harm patients data.
Blockchain Maturity & Use Cases	Blockchain maturity means that the technology has been used, tested, and the capabilities have been proven that includes use cases, skills availability, and knowledge. This factor measures the activities and efforts of the healthcare organizations to understand, prove, and test the blockchain technology through use cases, prototypes, and small projects. The activities that ensures the maturity of the technology understanding include understand the need for blockchain, translate it in technical requirements and develop it while keeping the product owner well informed, a specialized team with business experts, concept designers and development team specialized in blockchain is highly required.

You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for a summary of each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Infrastructure & Platform Integration												0
Standardization												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Infrastructure & Platform Integration												0
Security and Privacy												0
Total:												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Infrastructure & Platform Integration												0

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Blockchain Maturity & Use Cases												0
Total:												**0**

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Standardization												0
Security and Privacy												0
Total:												**0**

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Standardization												0
Blockchain Maturity & Use Cases												0
Total:												**0**

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
Security and Privacy												0
Blockchain Maturity & Use Cases												0
Total:												**0**

If you have comments, please provide them here:

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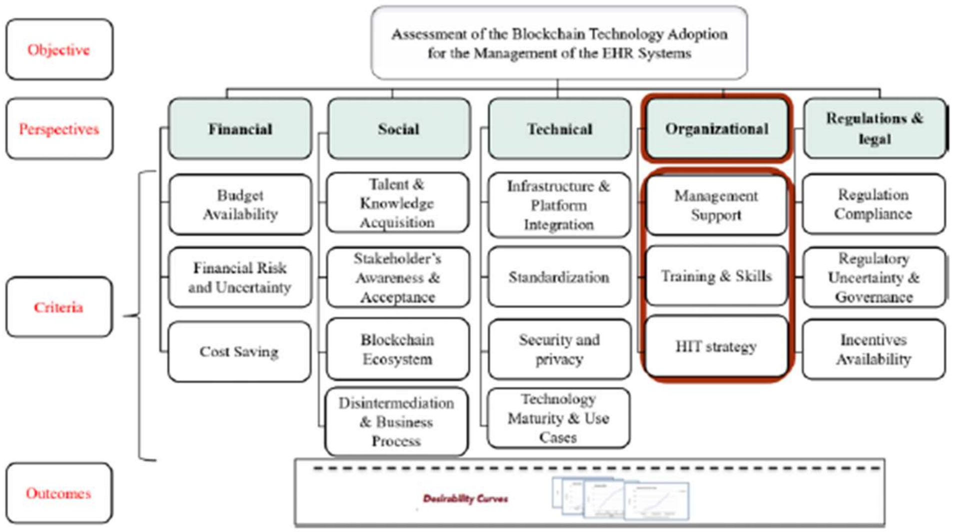
ɔck 13

Saeed Alzahrani PhD research - Model Ranking



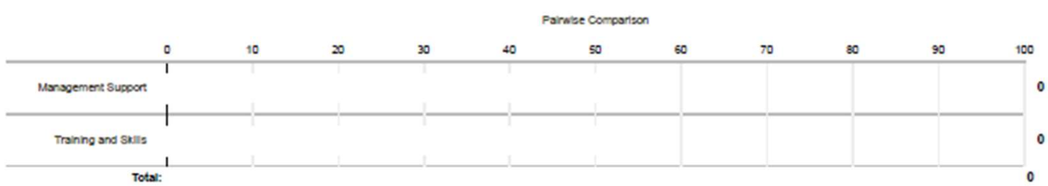
You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for a summary of each factor

Organizational Perspective	
Management Support	The top management support is an essential and a cornerstone in the successful Blockchain technology adoption. This factor evaluates the level of support, engagement, and approval of the top management to the Blockchain initiative.
Training and Skills	This factor measures the level of the healthcare organization's organized activities aimed at imparting information and /or instructions to help existing technical specialists involved with the Blockchain adoption, implementation, and maintenance attain the required level of knowledge or skill related to Blockchain solution as well as expedite the learning process. This includes data modeling and normal system availability as well as whether the solution is developed in-house or outsourced.
HIT Strategy	It is essential to understand the role of adopting Blockchain technology in achieving the higher-level strategic objectives of the healthcare organization and its HIT strategy. Blockchain adoption requires significant changes to the existing system in which organizations must strategize the transition. This factor measures the alignment of the Blockchain solution with the healthcare organization's IT strategy and objective of achieving a higher quality of care as well as its fitness with the much larger established health information ecosystem.

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.



Pairwise Comparison

Pairwise Comparison

	0	10	20	30	40	50	60	70	80	90	100	
	0	10	20	30	40	50	60	70	80	90	100	
Management Support												0
HIT Strategy												0
Total:												0

Pairwise Comparison

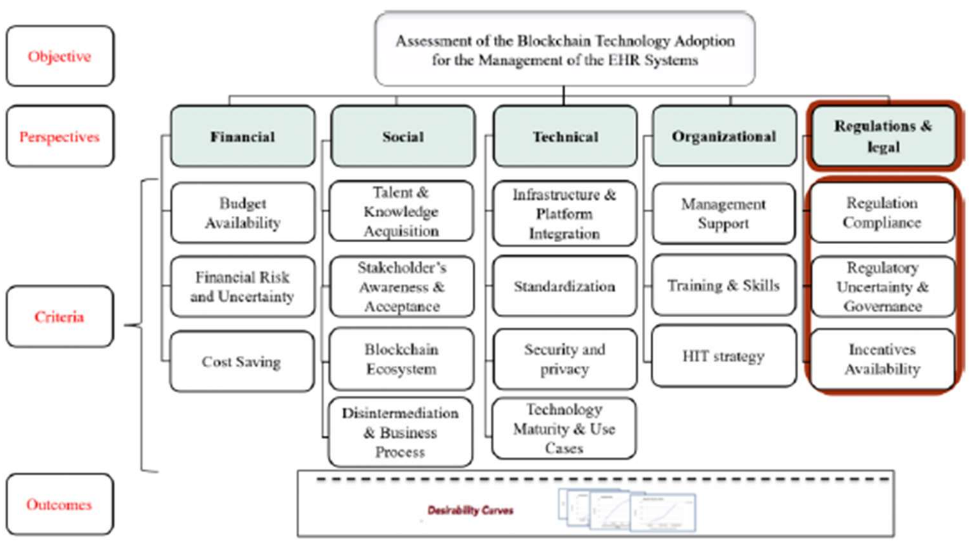
	0	10	20	30	40	50	60	70	80	90	100	
Training and Skills												0
HIT Strategy												0
Total:												0

If you have comments, please provide them here:

Please click on the next button (-->) on the right bottom of the screen

Block 14

Saeed Alzahrani PhD research - Model Ranking



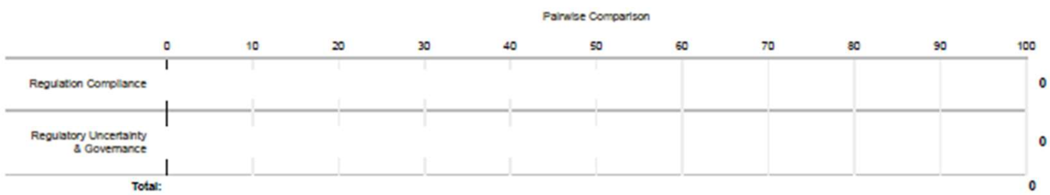
Regulations & legal Perspective	
Regulation Compliance	This factor measures the healthcare organization's effort to dedicate technology transfer and legal teams to guide the implementation efforts and understanding of the regulations associated with Blockchain technology such as HIPAA, PHI, data sharing, and technological laws in order to satisfy the compliance aspect, preserve data privacy, and adherence to privacy regulations.
Regulatory Uncertainty & Governance	This factor investigates the clarity and maturity of the consensus mechanism, access control, smart contracts, the rules that administrate the blockchain network, what data to be stored on-chain and off-chain as well as the flexibility to adapt to and address new changes in the regulatory landscape by assessing the legislative changes and take timely actions.
Incentives Availability	This factor examines the ability of the healthcare organization to work with partners and government officials as possible to determine technical, financial, and business incentives that could encourage organizations to adopt the technology and participate in the blockchain network.

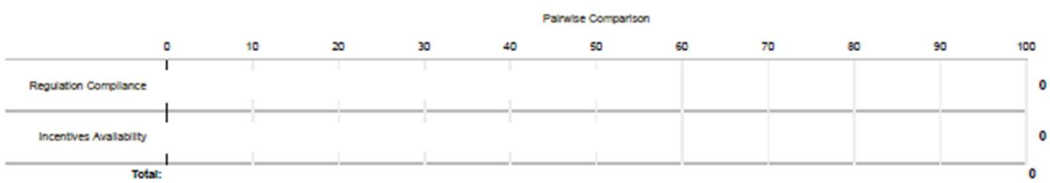
You will quantify the importance of each perspective through pairwise comparisons. Please read the instructions below:

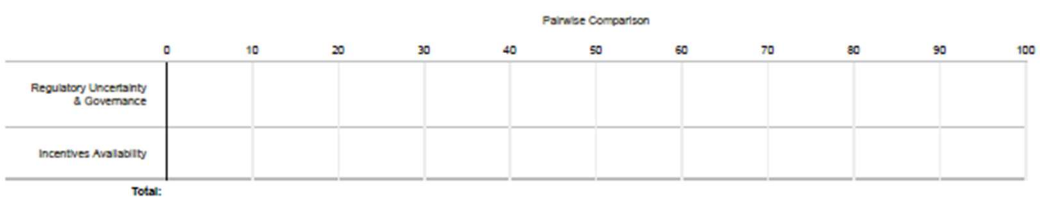
- Items will be compared against each other, in pairs. Assign the points according to your opinion.
- The assignment of points should reflect the importance of each item. Example: if A is 3x more important than B, A should receive 75 points and B should receive 25 points.
- Note that for each pairwise comparison, the total of points assigned must be 100.
- Please try to be logically consistent in your choices, i.e., if A is better than B, and B is better than C, A must be better than C.

Note: Please refer to the above table for a summary of each factor

Please judge the importance of the following factors dividing 100 points between them. Drag the bars below assigning more points to the one you deem more important.







If you have comments, please provide them here:

Please click on the next button (-->) on the right bottom of the screen

Block 7

Submission Confirmation

Thank you so much for your time and participation!

Please check the following if you would like to: (optional)

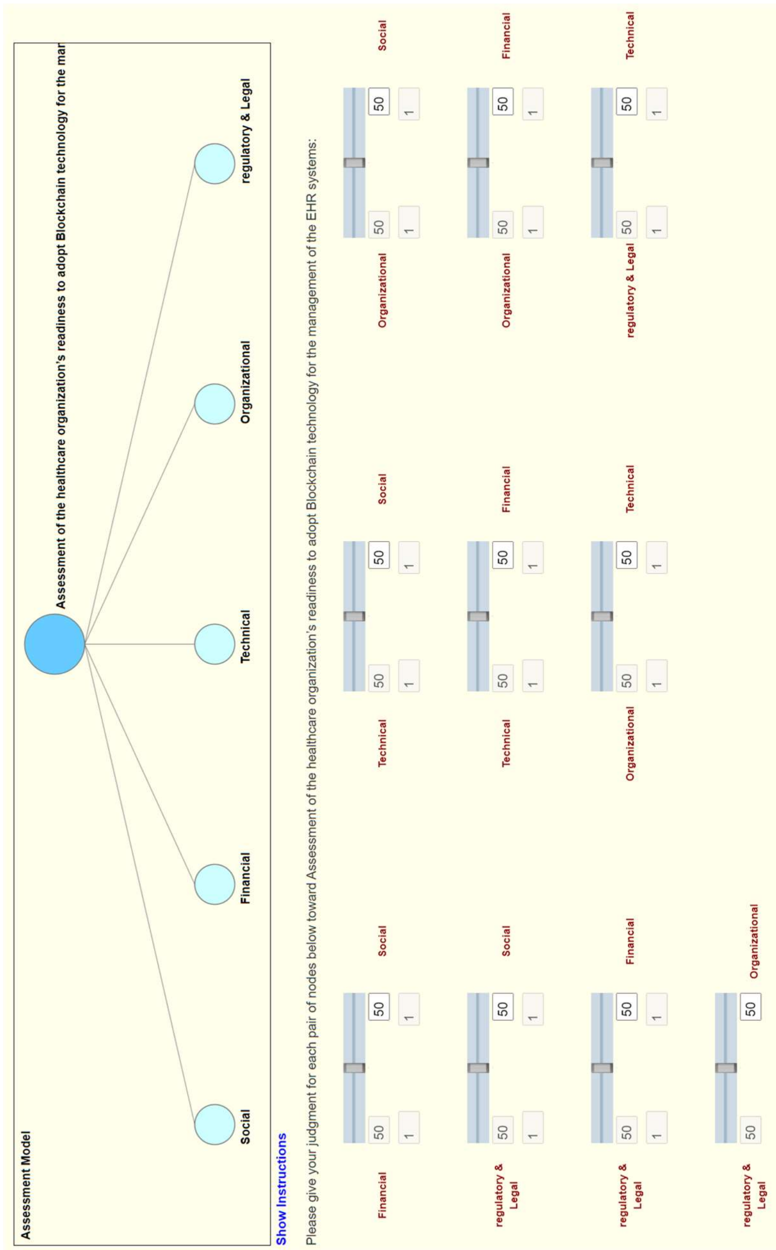
- ☐ Participate in another expert panel similar to the one you just completed
- ☐ Receive the results of this research (if checked, please enter your email address below)

By clicking on the " -->" button, your answers will be submitted.

Appendix D: HDM SOFTWARE TOOL

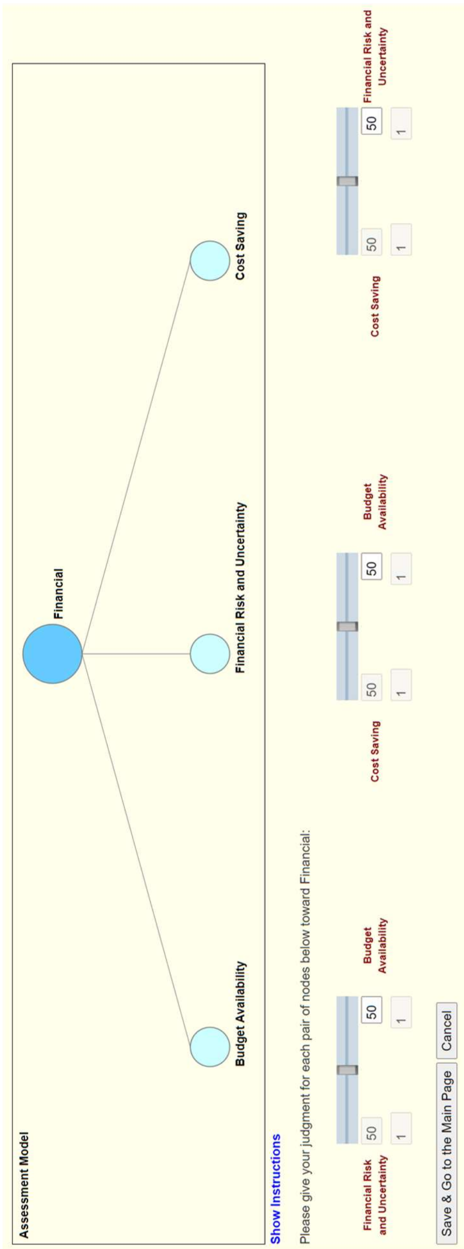
Objective (perspectives level):

http://research1.etm.pdx.edu/hdm2/expert.aspx?id=4583acd11ae9c7d0/96b70ea97a81fcc4!A01



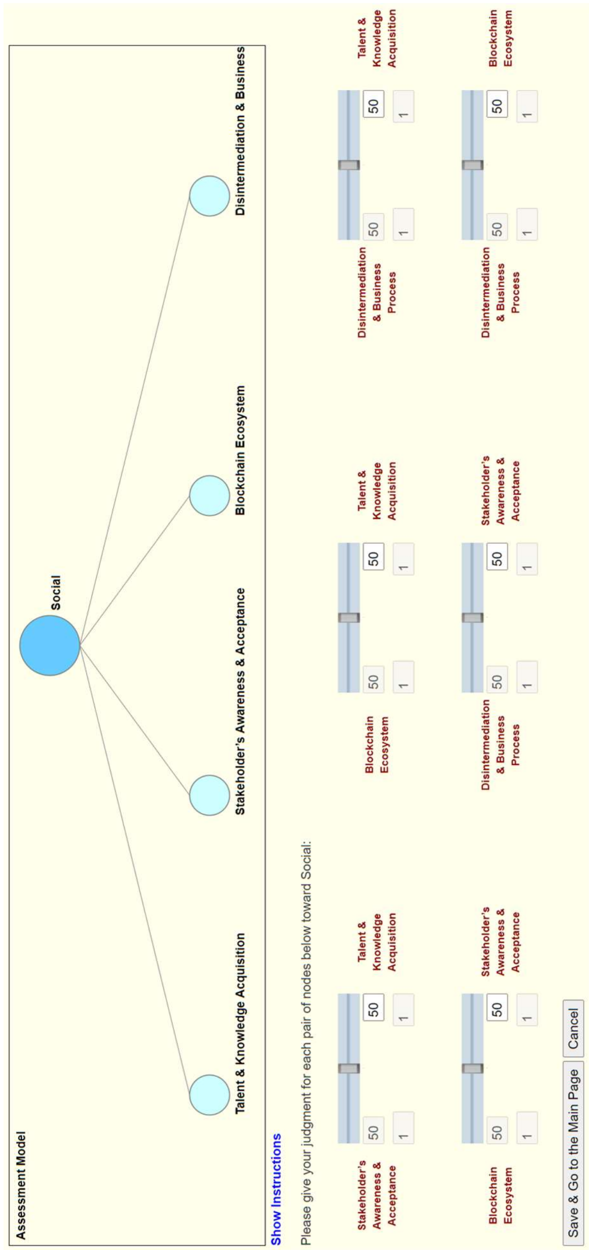
Financial Perspective:

http://research1.etm.pdx.edu/hdm2/expert.aspx?id=4583acd11ae9c7d0/96b70ea97a81fcc4!B02



Social Perspective:

http://research1.etm.pdx.edu/hdm2/expert.aspx?id=4583acd11ae9c7d0/96b70ea97a81fcc4!B01



Technical Perspective:

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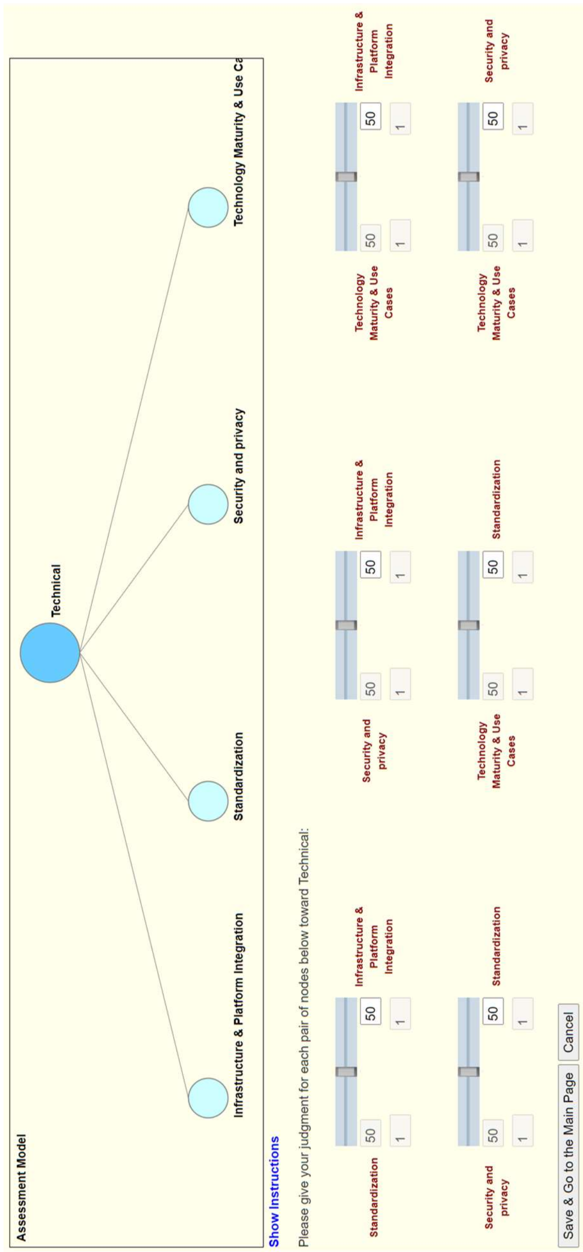

Organizational Perspective:

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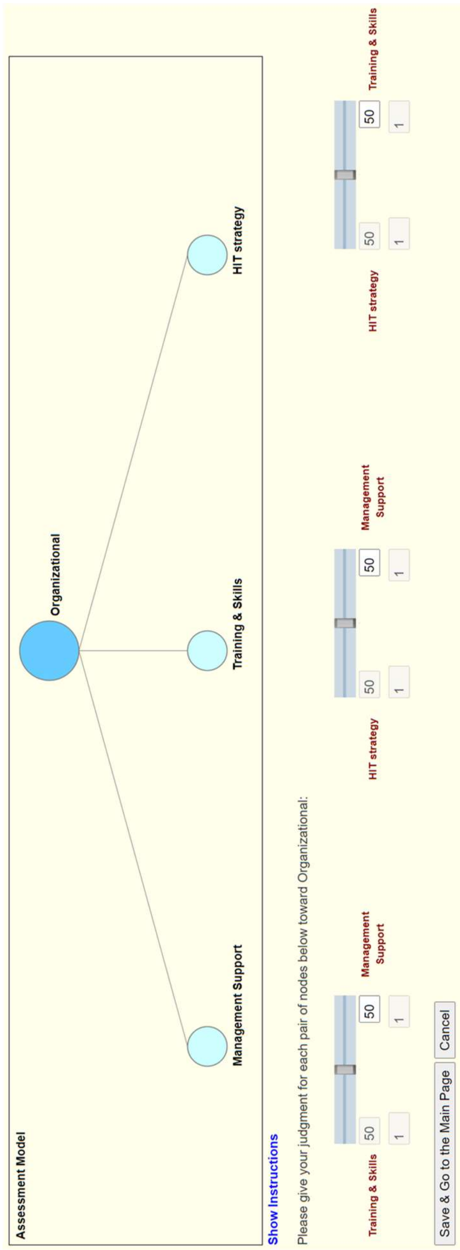

Regulations & Legal Perspective:

http://research1.etm.pdx.edu/hdm2/expert.aspx?id=4583acd11ae9c7d0/96b70ea97a81fcc4!B05