A Readiness Assessment Framework for Blockchain Adoption: A Healthcare Case Study

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Abstract

Blockchain technology is receiving significant interest. It has the potential to immensely benefit the healthcare sector, given the sector's inherent complexities, problems, and inefficiencies. However, to date, no comprehensive, evidence-based effort has been made to understand the readiness of this sector for blockchain adoption. A readiness assessment framework that includes the complex interplay of different underlying factors, social structures, and institutional mechanisms and that covers all key stakeholders is proposed. Developed following a systematic literature review, the framework is applied to the UAE's healthcare sector and its applicability and usefulness established. The findings show the multifaceted significance of government readiness in driving blockchain initiatives. Large firms are found to be more willing to leverage the opportunities afforded by blockchain. Lack of clarity on blockchain regulations and laws, and issues pertaining to privacy and trust are found to affect the readiness of all stakeholders. The suggested framework and the study's findings are useful in guiding policy interventions and developing support mechanisms to strengthen areas related to blockchain adoption.

Keywords: Blockchain, readiness assessment, theoretical framework, healthcare, COVID-19, UAE

1. Introduction

Blockchain or distributed ledger technology has attracted significant interest in recent years (White et al., 2020; Marsal-Llacuna, 2017). Governments and businesses in various sectors are exploring ways to exploit the disruptive potential of this technology, which provides immutable, transparent, secure, and trustworthy solutions in both public and private settings (Casino et al., 2019). Among the various sectors, healthcare is highlighted as one of the key sectors to potentially benefit from blockchain adoption (McGhin et al., 2019; Tandon et al., 2020). Blockchain appears to be a natural fit for overcoming problems

and inefficiencies inherent to the healthcare sector, such as counterfeiting, inaccurate healthcare data, lack of stakeholder collaboration, and privacy and security concerns (Mettler, 2016; Chukwu and Garg, 2020; Onik et al., 2019).

However, a sector-wide implementation of any disruptive technology (such as blockchain) is challenging. Assessing the 'readiness' of new technology projects is critical; unanticipated challenges during implementation may result in failure (Razmi et al., 2009; Kiberu et al., 2019). Given that blockchain is only as strong as its weakest link, understanding differences in the readiness of the sector stakeholders is critical (Pólvora et al., 2020).

Despite this criticality, however, research on blockchain readiness assessment is nascent. We encountered only two studies (Ozturan et al., 2019; Vlachos et al., 2019), neither of which involved healthcare. Furthermore, these studies were narrowly scoped toward developing a blockchain readiness index score and did not take into account the perspectives of different stakeholders and their mutual interdependencies. This theoretical and empirical void motivated this work, which aimed to develop and apply a multi-dimensional blockchain readiness assessment framework for the healthcare sector. In realizing this aim, the following questions are answered: 1) Who are the key stakeholders, and how do they collaborate and/or cooperate? 2) What are the key readiness dimensions of individual stakeholders, and how do they influence the sector? 3) What are the key facilitating conditions?

This study makes several contributions. For its theoretical contribution, it presents a novel blockchain readiness assessment framework and then tests its applicability through a multi-method case study in the UAE healthcare sector. The proposed framework fills a considerable gap in the literature, especially in healthcare, where no such framework exists. The framework is also adaptable and, given its conceptual comprehensiveness, has the potential to be applied in any sector or country. We expect practitioners and policymakers to find this framework a valuable tool for assessing the readiness levels of key stakeholders and for understanding the multifaceted interplay of various factors and mechanisms. The study is timely; inefficiencies of the healthcare sector have been exposed by the COVID-19 pandemic, and the findings can guide policy interventions and support mechanisms to strengthen blockchain adoption in the healthcare sector.

The remainder of the paper is structured as follows. In the next section, a review of blockchain studies in the healthcare sector is undertaken. The development of the blockchain readiness assessment framework is discussed in section three. The fourth section details the methodology used in applying the framework. The research findings are presented in section five and further discussed in section six. We conclude in section seven with implications and suggestions for future research.

2. Literature Review

A systematic review of the blockchain literature was undertaken using the Scopus database because of its broad coverage of journals. Keywords used to identify the initial list included "blockchain" or "block chain." Conference proceedings, working papers, and book chapters were not considered to maintain rigor and quality of content.

The initial search identified all the studies of blockchain. After removing duplicates and limiting studies to those published in the business and management domain, the list was narrowed to 598 articles. Title and abstract screening were undertaken to further refine the list to studies that focused on healthcare in their investigations. Technical studies, such as those on blockchain architecture and algorithms, were excluded. The references cited in the shortlisted studies were also reviewed to identify (eight) additional articles, leaving twenty studies on blockchain in the healthcare sector for detailed synthesis.

Figure 1 summarizes the systematic review process followed.

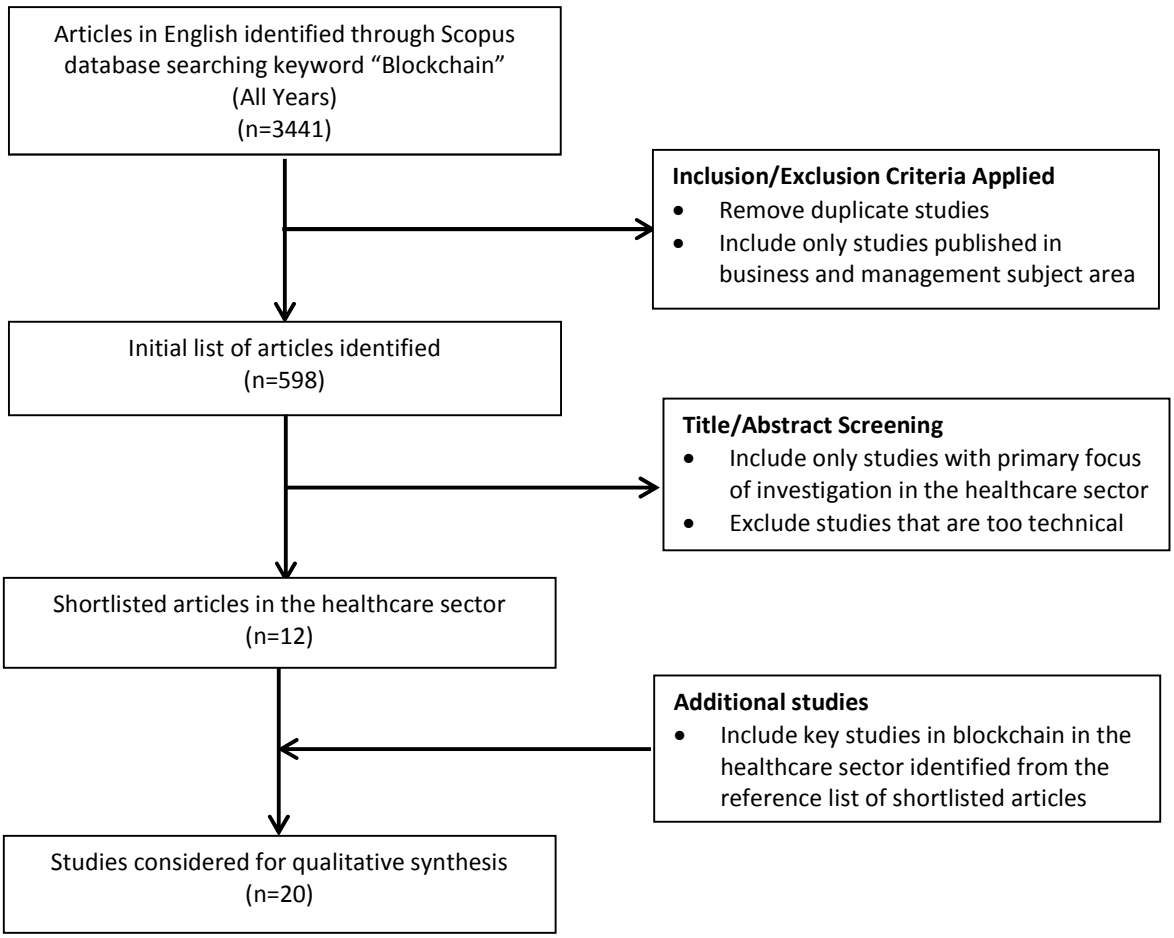

Figure 1. Systematic Review of Blockchain Studies on the Healthcare Sector

Our review of the studies (Table 1) revealed several gaps. First and foremost, no previous research was found to have examined the blockchain readiness assessment in the healthcare sector. Second, the studies were either descriptive or conceptual, using secondary data. Attempts to gain first-hand insights

into different aspects of blockchain adoption in healthcare through interviews, case studies, or surveys appeared limited. Also, a narrow emphasis was seen regarding understanding the interplay of underlying factors, social structures, and institutional mechanisms affecting the adoption of blockchain technologies.

Despite these gaps, careful syntheses of these studies enabled us to understand various applications of blockchain in healthcare, its benefits, and implementation challenges. The roles of key stakeholders associated with blockchain adoption in healthcare and their concerns related to various regulatory, privacy, and security issues were also understood. The review provided the initial conceptual base for the development of the blockchain readiness assessment framework.

Table 1. Summary of Blockchain Studies in the Healthcare Sector

Study	Country	Methodology	Primary Focus	Relevant Stakeholders*	Key Findings
Nugent et al. (2016)	UK	Experimental	Use of smart contracts	Regulators; pharmaceuticals	**Application:** Smart contracts; clinical trials with time-stamped data **Benefits:** Tamper-proof solution; enhanced trust and credibility; issues with clinical trials (missing data or data manipulation) can be addressed using blockchain.
Kuo et al. (2017)	Generic	Secondary research	Blockchain for biomedical and health care applications	Patients; business entities; service providers.	**Application:** Medical record management; insurance claim process; and clinical/biomedical research. **Benefits:** Decentralized management; immutable audit trail; data provenance; robustness/availability; and security/privacy. **Challenges:** Transparency; confidentiality; speed; scalability, and threat of a 51% attack.
Przhedetskiy et al. (2019)	Russia	Secondary research	Security and stakeholder cooperation	Government; healthcare institutions	**Application:** A mechanism for electronic interaction between the government and healthcare institutions using blockchain technology **Benefits:** Simplicity in information access to all stakeholders; reduction in data errors; less maintenance, enhanced transparency, and accountability of the data systems.
Bell et al. (2018)	Generic	Secondary research	Applications of blockchain	Patients; government; business entities; researchers	**Application:** Pharmaceutical traceability to fight counterfeiting; data sharing; overcoming fraudulent results in clinical trials; consent management; medical device/asset tracking
Gassner (2018)	Generic	Secondary research	Blockchain and General Data Protection Regulation (GDPR) compliance issues	Government; regulatory bodies; business entities; customers	**Benefits:** Integration of various tasks; enhanced transparency and accountability; privacy and confidentiality. **Privacy issues with GDPR:** Tensions between the rights to forget data in GDPR versus immutability of data in blockchain.
Katuwal et al. (2018)	Generic	Secondary research	Applications of blockchain	Business entities; service providers	**Application:** Management of Electronic Health Records (EHR), Genomic, and Imaging data; clinical trials and data sharing; supply chain visibility; prescription management; data analytics; telemedicine; and blockchain as a service. **Challenges:** Technical (interoperability, scalability); legal (adherence of regulation, data privacy); and governance (who controls the blockchain)
Radanovic and Likic (2018)	Generic	Secondary research	Applications of blockchain and challenges	Government; business entities	**Application areas:** Public health; medical education; health insurance; biomedical research; procurement; drug supply chain management **Challenges:** Lack of public and expert knowledge; data security and privacy
Dhagarra et al. (2019)	Generic	Secondary research	Sharing of medical records	Patients; government; business entities; researchers	**Application:** Medical record sharing with storage in the cloud; biometrics enabled smart contracts for data access; big data analytics on cloud data for various stakeholder decision making. **Success factors for implementation:** Internet penetration; a capable IT sector; experience with public-private partnership (PPP) model; a centralized and unique ID system. **Implementation barriers:** Technology barriers; lack of government support; intra-stakeholder, inter-stakeholder collaboration issues.

Study	Country	Methodology	Primary Focus	Relevant Stakeholders*	Key Findings
Dimitrov (2019)	Generic	Secondary research	Applications of blockchain	Patients; business entities	**Application:** Electronic medical record; data management; healthcare data protection; healthcare analytics; telemedicine, monetization of user controlled genomic data; smart contracts for patient data sharing.
Mackey et al. (2019)	Generic	Practitioner views	Governance of blockchain and applications	-	**Governance aspects:** Goal of the blockchain and the need for it; decision on blockchain design type (private, public, hybrid); data sharing and access (who and what); control (who has the control), incentive schemes **Application:** Privacy-preserving predictive models; licensing and credentialing of medical professionals; improvement of clinical trials; biomedical research; supply chain management; genomics
McGhin et al. (2019)	Generic	Literature Review	Challenges and opportunities of blockchain in healthcare	-	**Application:** Smart contracts; fraud detection; identify verification; clinical trials; precision medicine. **Benefits:** Interoperability; data sharing; mobility; security **Challenges:** Lack of standardization; privacy leakage; scalability; the threat of a 51% attack.
Onik et al. (2019)	Generic	Secondary research	Data privacy using blockchain	Customers; business entities; service providers	**Privacy concerns:** Privacy concerns of personally identifiable information **Application areas:** Intelligent data management; smart ecosystem; digital supply chain; IoT and big data; health claims; medication adherence; improved R&D; countering fake medicines. **Benefits:** Enhanced digital trust (security, identifiability, and traceability), the security of medical devices; interoperability and data sharing **Challenges:** Data storage on the blockchain; medical data volume and size; scalability; and privacy **Regulatory issues:** GDPR do not approve on-chain data storage, so data has to be stored off-chain
Patel (2019)	Generic	Secondary research	A framework for sharing of medical imaging data via blockchain	Patient; business entities	**Application:** Use of blockchain for distributed data storage and sharing of medical imaging data of patients **Benefits:** No need for third-party intermediaries (clearing houses) as it enables patient-controlled image sharing; facilitates interoperability between providers; no need for the use of physical copy (e.g., a CD or DVD) and courier service for data transfer. **Challenges:** Privacy and security concerns; perceived ease of use in using the system for patients; and regulatory compliance.
Siyal et al. (2019)	Generic	Secondary research	Applications of blockchain; implementation challenges	Patient; business entities	**Application:** Individualized and life-long patient care data on the blockchain; clinical trials; pharmaceutical supply chain management; countering fake drugs; biomedical research in precision medicine; neural control systems for storing brain data. **Benefits:** Longitudinal patient data (valuable for chronic diseases); patient control of data; security and privacy; audit control of data; enhancing data integrity in clinical trials – enrolling patients, getting their consent. **Challenges:** Privacy in the absence of the third party for authorization; the threat of a 51% attack; blockchain not designed for heavy data generated

Study	Country	Methodology	Primary Focus	Relevant Stakeholders*	Key Findings
					by the medical industry; interoperability between multiple blockchains; social acceptance by professionals; and limited solution providers.
Yoon (2019)	Generic	Opinion piece	Patient-centric blockchain	Patients	**Benefits:** Transition from institutional-driven interoperability to patient-centered interoperability. **Challenges:** Sensitivity and volume of medical data would result in it being stored somewhere else, and only tag that information on the blockchain.
De Aguiar et al. (2020)	Generic	Secondary research	Applications of blockchain; implementation challenges	Business entities; service providers; customers.	**Application:** Sharing healthcare records; sharing imaging in radiology safely; securing logs generated in accessing patient information; remote care; and supply chain management. **Challenges:** Throughput; latency due to increasing transactions causing a delay in diagnosis; security risks, resource consumption; usability issues due to technical complexity; and privacy concerns.
Albahli et al. (2020)	Saudi Arabia	Secondary research	User-controlled data sharing	Patients; business entities; service providers	**Application:** Patient data sharing using a combination of public and private blockchain with users owns their data on the cloud.
Chukwu and Garg (2020)	Generic	Literature Review	Blockchain as an alternative to EHR	-	**Benefits:** Enhanced trust; security; and privacy **Challenges:** High costs; lower performance; and data storage issues
Khatoon (2020)	Ireland	Secondary research	Developing a smart contract system	Patients; business entities; researchers.	**Application of blockchain:** Medical record handling and sharing with multiple stakeholders **Benefits:** Low cost of smart contract; enhanced auditability; interoperability; and accessibility.
Tandon et al. (2020)	Generic	Literature Review	Development of a framework for Block-chain based healthcare ecosystem	Patients; business entities; government; service providers	**Application of blockchain:** Medical diagnostics; research; treatment protocol; and disease calibration. **Benefits:** Enhanced performance and value creation **Challenges:** Costs; data protection and data sharing concerns; and security concerns **Regulatory issues:** Compliance and data ownership issues

**Blank means specific stakeholders are not considered in those studies*

3. Developing the Blockchain Readiness Assessment Framework

3.1. Components of the Assessment Framework

The components of the framework were derived from key technology readiness assessment framework–related studies of blockchain (Ozturan et al., 2019; Vlachos et al., 2019), e-health (Li et al., 2012; Rezai-Rad et al., 2012; Kiberu et al., 2019), e-records (Malanga & Kamanga, 2019), cloud computing (Colicchio et al., 2015), enterprise resource planning (Razmi et al., 2009), and e-government (Shareef et al., 2008).

Though most of these studies were narrow in scope, they provided a strong theoretical foundation for the development of the proposed framework. Combining existing frameworks into a comprehensive framework allows simultaneous investigation of multiple theoretical perspectives (Carter & Easton, 2011). While we concede that no single framework is sufficient to fully assess the readiness of a sector, a concerted effort was made to ensure the comprehensiveness of the proposed framework. This included addressing pitfalls in the existing readiness frameworks as well as contextualizing (as opposed to aggregating) these frameworks. Thus, the key components of the proposed framework are not directly inherited from other sectors; instead, it was carefully crafted and contextualized based on our understanding of the healthcare sector and blockchain technologies.

For instance, most studies have looked at readiness at an organizational level (e.g., Razmi et al., 2009). However, because stakeholders (e.g., service providers, governments, consumers) have different levels of readiness, readiness assessment at the firm level may not provide a complete picture (Li et al., 2012). The central task when developing any technology-oriented readiness assessment framework is defining the key stakeholders responsible for technology adoption. This is especially true for a multi-stakeholder–operated sector like healthcare, where the weakest one determines the blockchain's strength (Chukwu & Garg, 2020). Gaining acceptance from all stakeholders is important for blockchain's sector-wide adoption. The key stakeholders identified in the literature review are i) governments, ii) business entities, iii) blockchain solution providers, and iv) customers/end-users (Table 1). The subsequent goal of the framework is to assess the readiness levels of individual stakeholders. The four key dimensions identified by the literature are motivational readiness, engagement readiness, technology readiness, and structural readiness (e.g., Li et al., 2012; Rezai-Rad et al., 2012; Kiberu et al., 2019).

Next, assessing engagement levels among stakeholders, which has been missing from existing frameworks, is important; the main roadblock to blockchain adoption is their lack of cooperation, collaboration, communication, and coordination (Dhagarra et al., 2019). Understanding and enhancing multi-stakeholder relationships are, therefore, critical for blockchain adoption in healthcare (Katuwal et al., 2018; Pólvora et al., 2020).

The final aspect of the framework is understanding of the facilitating conditions required for blockchain adoption. This is critical because these conditions could directly influence the readiness of stakeholders. While studies have considered some facilitating conditions in their assessment frameworks, most have overlooked several key conditions. Those most relevant for blockchain adoption in the healthcare sector include regulatory and legal aspects, innovation propensity, privacy and trust, and supporting infrastructure (e.g., Dhagarra et al., 2019; Gassner, 2018; Onik et al., 2019).

3.1.1. Key Stakeholders

Governments: They are regarded as the most important stakeholder as their involvement in blockchain adoption can be multiple. First, they can themselves implement blockchain solutions to make public sector services more efficient, secure, and transparent (Nugent et al., 2016; Przhedetskiy et al., 2019). Also, governments can encourage other stakeholders to implement blockchain solutions by designing blockchain-friendly legislation or by providing related funding or incentives such as tax exemptions (Clohessy & Acton, 2019).

Business Entities: "Business entities" here refers to the complex network of organizations in the healthcare sector, such as healthcare service providers (hospitals, clinics), pharmacies, insurance providers, health research centers, and drug and equipment manufacturing companies, among others. Depending on the blockchain solutions, the involvement of all or a limited number of business entities is required. For instance, for the implementation of a patient records management system, the direct participation of manufacturing companies or research centers may not be required, though they may be interested. By contrast, for an end-to-end supply chain traceability solution in the blockchain (to tackle counterfeit goods), all supply chain entities from research centers to pharmacies would have to be involved. Typically, business entities have the option of either developing their own blockchain solutions /or participating in others'.

Blockchain Solution Providers: These are companies such as IBM, Microsoft, Amazon, and consortiums such as R3 that provide purpose-built tools to implement blockchain solutions. The healthy competition among these large corporations is facilitating faster adoption of blockchain solutions. There are also over 11,000 startups offering blockchain solutions for businesses and governments, with a significant number receiving funding (Tracxn, 2020). The healthcare sector is receiving increasing attention from these companies and startups. For instance, the IBM Rapid Supplier Connect blockchain network was developed during the COVID-19 pandemic to equip frontline workers with equipment. This platform enables governments, hospitals, pharmacies, and others to locate pre-qualified suppliers of medical gowns, surgical masks, and gloves with greater efficiency (IBM, 2020).

Customers/End-users: The willingness and ability of customers to participate in a blockchain ecosystem are critical to its widespread adoption. Thus, most blockchain solutions are customer-centric as opposed to institution-centric (Yoon, 2019). Customers should see tangible payoffs in participating in blockchain-enabled services. This is even more relevant to healthcare, where patients have the rights to consent and to choose how their data is used in exchange for health services or even compensation (Albahli et al., 2020). This shift from provider-centric to patient-centric permissioned blockchain system empowers the patient and provides an immutable audit trail of whose, when, where, and what personal health data is accessed (Mackey et al., 2019). The need for patient-centric healthcare is expected to promote the sector-wide adoption of blockchain solutions.

3.1.2. Dimensions of Individual Stakeholder Readiness

Motivational Readiness: Also known as "core readiness," this refers to a recognized need for change vis-à-vis an existing service or circumstance (Kiberu et al., 2019). It usually starts with dissatisfaction with

practices or services presently offered (Li et al., 2012). Unless this motivation is activated, an individual or organization is unlikely to initiate change in behaviors. In the healthcare sector, for example, this could be a realization of problems pertaining to poor service or breached patient privacy.

Engagement Readiness: This refers to knowledge and awareness of new initiatives as well as clear recognition of their benefits and potential challenges (Li et al., 2012; Rezai-Rad et al., 2012; Kiberu et al., 2019). For blockchain technologies, this includes knowledge of how they function, potential impacts on current systems, difficulties related to developmental costs, risks of failure, and potential benefits of smart contracts (Ozturan et al., 2019). Any stakeholder with high engagement readiness would explore the possibility of using blockchain technology as well as express any fears or concerns about using the technology.

Technology Readiness: This refers to individual or organizational predispositions to embrace new technologies (Kamble et al., 2019). The contributing factors of this readiness include the availability, ability, and compatibility of existing hardware, software, networks, applications, and other information and communications technology (ICT) resources that facilitate the new technology (Kiberu et al., 2019). Further, the robustness of an organization's security infrastructure, cloud infrastructure, and internet connection bandwidth also contributes to technology readiness (Rezai-Rad et al., 2012; Kiberu et al., 2019). In the case of individual customers, this refers to having access to/ownership of technologies such as personal computers, tablets, smartphones, high-speed internet, and 4G/5G mobile connectivity.

Structural Readiness: This refers to the availability of non-technical resources—financial and human resources—to invest in the adoption of new processes or technologies, as well as having supporting organizational structures and policies in place (Li et al., 2012; Kiberu et al., 2019). Implementation of blockchain technologies would demand valuable resources, such as time, money, and personnel, from an organization. Organizations with greater resource availability, such as ICT experts, would be more confident in implementing blockchain technologies (Rezai-Rad et al., 2012). Conversely, resource scarcity could hinder the pursuit of new initiatives. From a customer perspective, structural readiness relates to the ability to use computers, smartphones, and the internet for daily tasks (Rezai-Rad et al., 2012).

3.1.3. Key Stakeholders Relationships for Blockchain Adoption

Governments and Business Entities: Public-private collaboration is important to co-designing and piloting innovative blockchain projects (World Economic Forum, 2019). For instance, the US Food and Drug Administration (FDA) worked with Pfizer, a pharmaceutical company that has lost billions in revenue due to counterfeited drugs, on an RFID-based blockchain solution where patients and doctors could trust the source and capabilities of medicines. This also allowed wholesalers and pharmacists to verify the authenticity of medicines using a simple RFID scanner (Bell et al., 2018). The European Commission Research & Innovation Program has developed a pilot project, "Blockchain-Enabled Healthcare," in partnership with Novartis on the Ethereum platform (Dimitrov, 2019). Russia has effectively rolled out blockchain technologies in the healthcare sector, using effective public-private partnerships (Przhedetskiy et al., 2019).

Government and Blockchain Solution Providers: For large-scale government projects, developing formal partnerships with established blockchain solution providers and working closely with them is essential. For instance, the government of Estonia has worked with Guardtime, an enterprise blockchain solution provider, to develop the world's largest blockchain platform, and almost 100% of government services, including healthcare, are offered through this platform (Onik et al., 2019; Siyal et al., 2019; Chukwu & Garg, 2020). In the healthcare sector, for example, Booz Allen Hamilton Consulting developed and implemented a blockchain-based pilot on the Ethereum platform; it was designed to help the FDA explore using the technology for healthcare data management (Dimitrov, 2019).

Government and Customers: Governments worldwide are attempting to be more efficient by reaching out to people directly without intermediaries. For example, Smart Dubai, a Dubai government initiative, has developed a blockchain platform that allows citizens, residents, visitors, and businesses to pay online for government transactions (Smart Dubai, 2020a). In 2018, Smart Dubai conducted more than 10.4 million transactions through its blockchain platform (World Economic Forum, 2020). The United Nations' World Food Programme has used blockchain technology to help more than 10,000 Syrian refugees in Jordan receive rations from supermarkets near their camp. The blockchain system uses retina scans instead of cash, vouchers, or e□cards, thereby ensuring that food reaches the right person (World Food Programme, 2017). In Estonia, 99% of patients have access to their digital health records through their country's blockchain platform (Chukwu & Garg, 2020).

Business Entities and Blockchain Solution Providers: A close association between various business entities and blockchain solution providers, including niche and startup providers, is critical for novel blockchain solutions. For instance, researchers at Massachusetts General Hospital, a top-five US hospital, are collaborating with Korean blockchain startup MediBloc to find better ways to store and share patient data (Waxman et al., 2019). Similarly, several pharmaceutical companies have collaborated with software corporation SAP on blockchain solutions for supply chain tracking and fake drug identification during the COVID-19 pandemic (Bio World, 2020). IBM is leading a multi-stakeholder collaboration with healthcare service providers, insurance providers, and banks to create a blockchain healthcare network for information exchange that improves transparency and interoperability (Reuters, 2019).

Business Entities and Customers: The need for direct, fast, and automated interaction between business entities and customers is rising. Wang et al. (2019) highlighted the importance of activating blockchain technology to deepening consumer relationships. Their study found that blockchain applications can improve both intrinsic and extrinsic motivations of customers in loyalty programs. AXA, a leading French insurance group, has developed its own Ethereum-based platform called "Fizzy." It offers automatic flight delay insurance for its customers, thus avoiding the need for additional paperwork (Radanović & Likić, 2018). In the healthcare sector, companies have realized the value of dealing with customers directly, enabled via blockchain. For example, Nebula Genomics offers whole-genome sequencing free for customers in return for data ownership to build their blockchain-based genetic marketplace (Ahmed & Shabani, 2019).

Blockchain Solution Providers and Customers: Consulting firms such as Deloitte have developed proofs-of-concept for customer-centric blockchain solutions such as Know Your Customer (KYC). This complete

customer profile will be useful for financial institutions, insurance companies, exchanges, and solutions vendors. It allows a seamless onboarding experience for customers and eliminates costly background checks and overhead (George et al., 2019). Deloitte has also developed a blockchain proof-of-concept for automobile loans that simplifies the lending process. It creates an automobile loan marketplace that connects dealers, lenders, and customers through the blockchain network and facilitates the process of smart loans (Deloitte, 2020). In the healthcare sector, EpigenCare, a blockchain startup, uses blockchain technology to recommend beauty products to customers directly by examining their DNA and skin epigenetics (PR Newswire, 2018).

Multi-stakeholder Engagement

In addition to dyadic relationships between stakeholders, multi-stakeholder engagement, including with competitors, is critical for developing blockchain solutions (Pólvora et al., 2020). For instance, the US FDA has worked with four companies—IBM, Merck, KPMG, and Walmart—on a pilot project developing an interoperable system that will identify and trace prescription drugs (FDA DSCA, 2020). Similarly, MiPasa is a multi-party (involving IBM, Microsoft, the Wharton School, and scientists), multi-source verifiable data-sharing blockchain platform that was established to provide timely, trustworthy data as well as associated analytics on the COVID-19 outbreak (MiPasa, 2020).

2.1.4. Key Facilitating Conditions

Supportive Regulatory and Legal Structures: This includes government policies, directives, regulations, laws, and judicial interpretations (Vlachos et al., 2019). Depending on the appetite for innovation, policies can be either restrictive or permissive. Leaning too far on either end of this spectrum can yield negative results: stagnation if the policy is too restrictive, or harmful compromise if it is too permissive (Kimani et al., 2020). Many blockchains are associated with smart contracts; the legal validity of these contracts, as opposed to traditional ones, could be a concern for businesses (Giancaspro, 2017). These concerns would be even more valid in healthcare, where a patient's health or even life could be at stake (McGhin et al., 2019). Therefore, to facilitate blockchain adoption, regulatory and legal frameworks must evolve in parallel with the development of new blockchain applications, and blockchain applications must learn to comply with these regulations.

Innovation Propensity: Innovation culture is critical to the widespread adoption of blockchain. Several studies have used innovation theory to explain blockchain adoption (Clohessy & Acton, 2019). Here, innovation includes not only technological innovation but also service innovation, service delivery innovation, administrative and organizational innovation, conceptual innovation, policy innovation, and systemic innovation (Windrum, 2008). Supportive policies and public-private partnerships to bolster innovation are likely to facilitate additional blockchain applications (Dhagarra et al., 2019).

Privacy and Trust: Sensitive and personal healthcare data must be handled with the utmost privacy and trust because of their potential for abuse and discrimination. According to a global IPSOS/World Economic Forum study in 2019, 41% of people do not trust their healthcare providers with regard to their private data (IPSOS, 2019). According to estimates, an individual patient's data could be worth as much as 7,000 USD per year (Dimitrov, 2019). Assuring stakeholders that their information is private, safe, and

anonymous is critical for the adoption of blockchain applications. Stakeholder trust in the blockchain technology as well as the blockchain consensus mechanisms (participants agreeing to trust the network consensus) are also essential, especially for automated smart contracts (Mackey et al., 2019; Onik et al., 2019). While the blockchain itself may be trustworthy, in the case of private-permissioned blockchains, the network participants must be carefully selected as they will have access to sensitive data on the chain.

Supporting Infrastructure: These are diverse factors that act as accelerants for blockchain adoption. They include attracting and supporting startups developing blockchain technologies, such as through accelerator programs (Vlachos et al., 2019). The other critical factor that hastens blockchain adoption is the ability of the sector to attract investors to fund blockchain companies and projects (Vlachos et al., 2019). Collaboration with sectors such as telecommunications and cloud solution providers also enhances blockchain solution–related infrastructure (Dhagarra et al., 2019).

3.2. Proposed Readiness Assessment Framework

Figure 2 shows the proposed integrated readiness assessment framework for blockchain. Central to the framework is the stakeholders and their strategic relationships. The overall readiness of each stakeholder is captured through the four readiness dimensions. Finally, the differential influence of the facilitating conditions on the readiness of stakeholders is captured. The framework provides a comprehensive approach for researchers and policymakers to assess the blockchain adoption readiness of the healthcare sector or any other sector in any country.

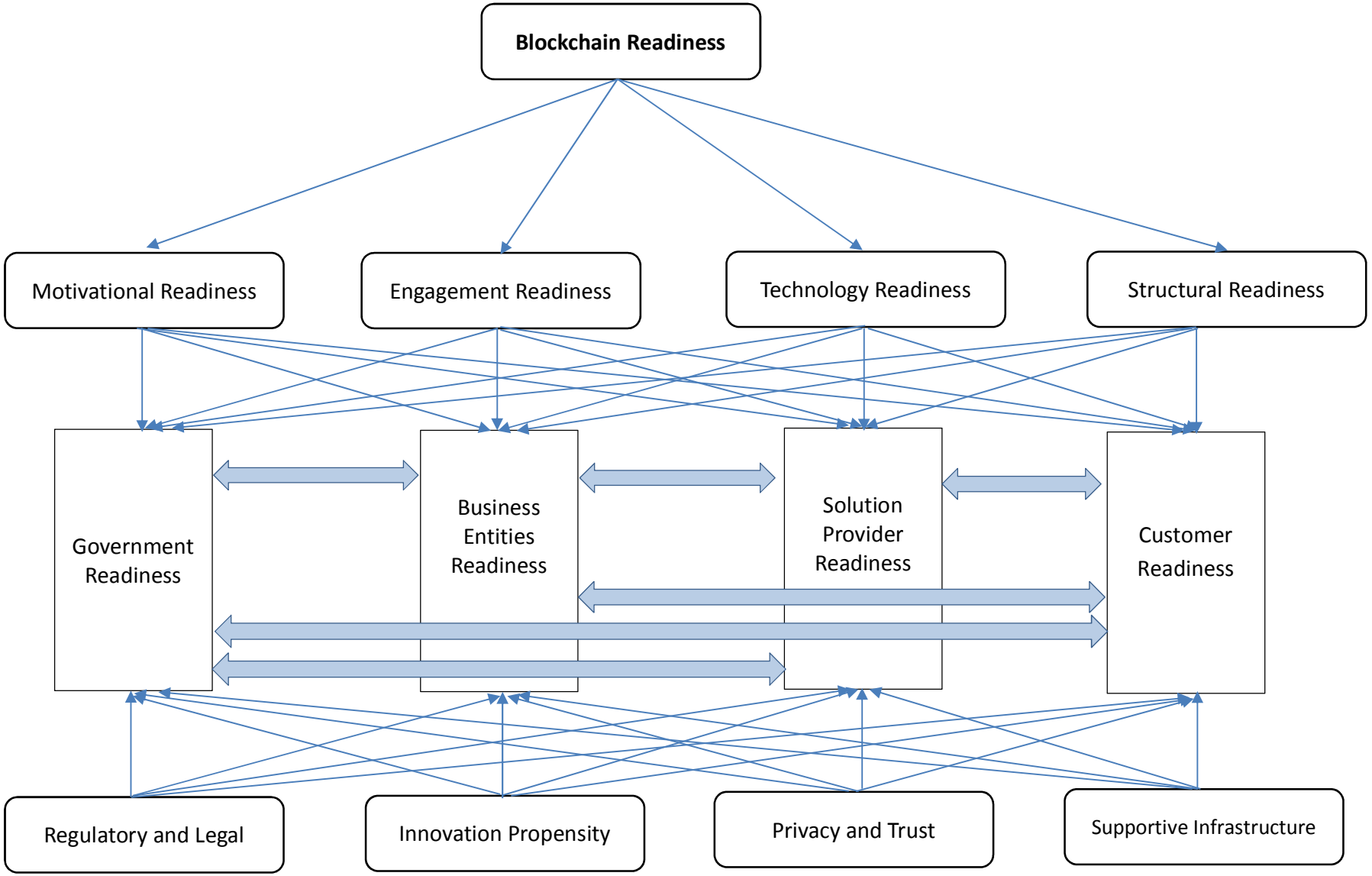

Figure 2. Blockchain Readiness Assessment Framework

4. Application of the Framework in the Healthcare Sector

Once we developed the assessment framework, the next stage was to test its applicability. While it could be tested anywhere, a setting that is experiencing a significant push toward blockchain adoption and healthcare advancement could be more practically relevant. The UAE was chosen as the case country as it is among the few countries in the world to have adopted a national blockchain strategy (UAE, 2020). Providing world-class healthcare is also one of the six pillars of the UAE agenda (UAE Vision 2021, 2019). Thus, the UAE provides an ideal setting to assess opportunities and challenges associated with blockchain adoption in healthcare.

A case study approach was deemed most appropriate because we were examining a contemporary topic in a real-world situation (Yin, 2009). Although the study adopted was a single case design (UAE healthcare sector), it featured an embedded case design with multiple units of analysis (Yin, 2009). In terms of methods, a pragmatic, sequential multi-methodology approach was employed to develop a comprehensive understanding of various strands of the framework and, in the process, answer the research questions. The use of a pragmatic approach was justified given that practical, realistic solutions are needed to inform practice, especially considering the newness of the topic. Therefore, as in other case study research into blockchain, empirical data were compiled via multiple methods and sources (Islam et al., 2019), as shown in Table 2.

Table 2. Summary of Primary and Secondary Information Sources

Primary Sources	**Secondary Sources**
Interviewee 1 – Chief Technology Architect - Experience - 25+ years in IT - Responsible for leading the blockchain initiative at the hospital Interviewee 2 – IT Security and Compliance Lead - Experience - 30+ years in IT - Expert knowledge in blockchain technologies and has led several blockchain projects Interviewee 3 –Head of Fintech, Blockchain & Emerging - Experience - 15 years in the legal field - Expert Legal Consultant, responsible for advising government agencies, businesses as well as startup advisor on blockchain and other emerging technologies Interviewee 4 -Service Delivery Manager, Infrastructure & Data Center - Experience – 12 years in IT - Expert in Cloud computing and blockchain technologies Interviewee 5 – Healthcare Researcher (Government entity) - Experience – 10 years as healthcare researcher - Expert in healthcare policies and regulatory compliance of new technologies ***Interviews with Customers*** - Six customer interviews - The average number of years residing in the UAE – 9 years	• Industry reports - *e.g., Pricewatercoopers, KPMG* • Government reports • Global Organizations Report – *e.g., World Bank, World Economic Forum* • Government policy documents • News Articles • Websites • Global Survey Reports - e.g., *World Economic Forum, United Nations* • Industry Case Studies • Successful Use Cases • Miscellaneous – *e.g., Blogs, Public forums*

- Three working professionals and three homemakers ***Survey with Customers*** - 22 responses from 100 random samples (22% response rate) - The average number of years residing in the UAE – 9 years - All working professionals	

First, qualitative, secondary data from reliable sources relevant to blockchain adoption in UAE healthcare (refer Table 2) were assembled, coded, and analyzed in line with the research questions. To ensure reliability and rigor in the secondary data, we considered only reports from leading consulting firms, governments, and global organizations.

In the next phase, primary research was conducted to complement the secondary sources and to fill gaps in the secondary sources. For consumers, primary data were collected in two consecutive phases using a sequential explanatory design. First, a customer/patient-centric survey was conducted, followed by semi-structured interviews with individuals residing in the UAE for at least five years.

The non-technical, random-sample survey (response rate of 22%) targeted 100 residents. The survey assessed their general willingness to voluntarily share data with other stakeholders; privacy and security concerns regarding their healthcare data; the effort taken to gage whether the medical products they purchased were original; the importance allocated to the country of origin of products; the need to have access to healthcare data at any time; concerns relating to the quality of imported medicines/products; general awareness of blockchain and decentralized systems; and willingness to use/participate in these systems.

The in-depth semi-structured customer interviews involved six participants selected using a purposive sampling technique to encourage diversity of gender and nationality. Each interview was approximately 50–60 minutes. The interviewees were briefed on blockchain technology and probed on the lines of the survey questions and responses with a focus on “how,” “what,” and “why.” In addition, they were asked about the positives and negatives of the UAE healthcare system and changes they would like to see post-COVID-19 pandemic. Follow-up questions were also asked regarding anticipated benefits and challenges with the implementation of blockchain technologies, with cues occasionally provided to generate meaningful insights. The responses to the survey and interviews were then compiled with the secondary data to derive a meaningful generalization of customer readiness for blockchain adoption.

Additionally, five expert interviews were conducted to complement and triangulate the secondary findings and to identify discrepancies (if any). Again, purposive sampling was used to ensure we included key stakeholders with a strong understanding of blockchain technologies. The experts were probed on their readiness across different readiness dimensions, their association with other stakeholders, and the influence of various facilitating conditions. Interviews lasted 45–60 minutes.

The data drawn from the various sources (Table 2) were categorized and coded. Two authors independently coded the data to ensure consistency. The first stage involved a thematic analysis of data for each stakeholder. The categorized data for each stakeholder group were further identified and

classified into four readiness sub-themes. The second stage of the analysis involved axial coding, in which pairs of stakeholder groups were analyzed together to identify and code dyadic relationships. For this, data corresponding to stakeholder groups was examined together. For example, relevant data for the association between a government and a blockchain solution provider were coded and categorized. Any evidence of multi-stakeholder relationships (involving more than two stakeholders) or international stakeholder relationships (involving entities in different countries) were categorized separately and coded. In the third stage, the secondary and corresponding primary data were categorized and coded under the facilitating conditions. Finally, findings related to each stakeholder were summarized as "Low," "Moderate," or "High" based on the amount and strength of the evidence identified. To improve reliability, the summarization was conducted independently by two authors.

5. Case Study Findings

The findings are organized in line with the readiness assessment framework and research questions. However, before the findings are provided, an overview of the UAE healthcare sector is provided to give context.

The UAE healthcare sector has witnessed astonishing growth, from a few hospitals to over 125 public and private hospitals (US-UAE Business Council, 2018). The sector is competitive, with healthy rivalries among several foreign and domestic players. The UAE government has also implemented several citizen-centric initiatives in the sector. For instance, healthcare insurance is mandatory in the UAE, providing basic coverage for all citizens and residents. Also, medical tourism is on the rise; Dubai alone is expecting 500,000+ international health tourists annually by 2021. Blockchain has been recognized as a potential innovation area of focus for the sector (US-UAE Business Council, 2018).

5.1. Stakeholder Readiness for Blockchain Adoption

Stakeholder readiness gauges the extent to which UAE healthcare stakeholders are ready to support and promote the awareness, implementation, and use of blockchain solutions.

5.1.1. Government Readiness

The UAE government is not only the most important stakeholder for blockchain adoption—it is evidently the readiest. All expert interviewees agreed that the federal and state governments are the key stakeholders responsible for the growing interest in blockchain. Regarding the emirate level, participants highlighted various initiatives such as Dubai Health Strategy and Abu Dhabi Healthcare Strategic Plan (for developing a world-class healthcare ecosystem), demonstrating strong motivational readiness.

Interviewees also highlighted the UAE government's support of blockchain technology, particularly its Blockchain Strategy 2021 (UAE, 2020) and the fact that many public sector entities are adopting blockchain solutions (World Economic Forum, 2020). An interviewee from a government entity described several programs undertaken by the Dubai government, such as the "Dubai Blockchain Strategy" for migrating key government processes, including healthcare records, to blockchain and the "Dubai Blockchain Policy" encouraging businesses to adopt blockchain technologies, thereby demonstrating

strong engagement readiness. In technology readiness, the UAE was ranked first in the world in government procurement of advanced technology products (Network Readiness Index, 2019). The UAE government is also well-positioned from a structural readiness perspective as it is the largest spender in the healthcare sector.

5.1.2. Business Entity Readiness

Several issues related to motivational and engagement readiness were echoed throughout the interviews. According to respondents, core challenges facing UAE healthcare firms, especially small and medium enterprises (SMEs), in blockchain implementation are related to lack of knowledge and awareness, and regulatory rather than technical issues. One interviewee (from a blockchain solution provider) mentioned that many small firms are unfamiliar with the term "blockchain" but have heard of Bitcoin. According to a recent study of UAE SMEs, 63% of firms are unaware of industry 4.0 technologies, including blockchain, and their relevance to their business operations (Dubai SME, 2019). For SMEs that are aware of blockchain, according to respondents, their reluctance is potentially due to the poor reputation of cryptocurrency, and many firms perceive them as indistinguishable and are therefore concerned about legal and regulatory issues. This is in line with government findings that SMEs in the UAE are not adequately aware of key contemporary technologies and trends, thus, their preparedness for the adoption of such technologies in the near future is reduced (Dubai SME, 2019). This is a concern given that the majority (more than 95%) of businesses in the UAE (including in healthcare) are SMEs.

Most entities in the UAE private sector that have engaged with blockchain technologies are large corporations. Some of the successful use cases in blockchain implementation in the UAE involve large firms in banking (e.g., Emirates Bank), airlines (e.g., Emirates Airlines), logistics and supply chain (e.g., Dubai Ports), and telecommunications (e.g., Etisalat). As the interviews evidenced, this was primarily because the implementation of blockchain is part of the long-term strategic focus of large firms, while the focus of SMEs is more short-term and cost-oriented. One interviewee (chief technology architect responsible for blockchain implementation in a large multinational hospital) highlighted the importance of having a long-term strategy to leverage the full benefits of blockchain. Other respondents echoed this; firms looking to implement blockchain must not look for immediate but rather long-term benefits.

From technological and structural readiness perspectives, the readiness of UAE business entities is relatively high. Evidence from a recent study suggests that the readiness of private-sector firms to adopt current ICT is high; 98% in Dubai use computing devices with connectivity for daily business operations, and 74% use cloud storage. The percentage of SMEs in the UAE with a dedicated IT budget has increased from 27% in 2013 to 73% in 2019 (Dubai SME, 2019).

5.1.3. Solution Provider Readiness

The results of the interviews indicated that the general readiness of UAE blockchain solution providers across all four dimensions is relatively high. Many leading global enterprise IT and business consulting firms are actively involved in promoting blockchain in the UAE. Companies such as Microsoft, SAP, IBM, and Cisco are part of the Dubai Future Foundations' Global Blockchain Council (Dubai Future Foundation, 2020). Several large domestic enterprises have also started offering the blockchain platform. Over 120

blockchain companies are present in the UAE, including many startups; more than 200 projects are active (World Economic Forum, 2020). Leading consulting firms such as PricewaterhouseCoopers are working with governments and businesses to establish blockchain policies and strategies (PwC, 2019).

While general readiness is promising, the focus of blockchain solution providers on the healthcare sector is not. However, this is not a problem specific to the UAE given that healthcare sectors, in general, have been laggards in blockchain implementation. When we probed interviewees on the lack of focus on healthcare among blockchain solution providers, the respondents highlighted that this is mainly due to the complexity associated with the sector and compliance-related issues regarding patient data. According to the interviewees, other sectors, including the public sector, are considered low-hanging fruit by providers and are thus the focus. However, the respondents were confident that providers would eventually turn their attention to the healthcare sector. They stated that at present, the proof-of-concept to implementation ratio is very low in the healthcare sector. One interviewee from the healthcare sector mentioned that they were receiving calls from blockchain solution providers daily and that providers were sending technical materials and successful blockchain use cases regarding implementation. One respondent expressed a desire to see more niche blockchain solution providers in the fitness and wellness domains, two growth areas in the UAE. Another respondent expressed disappointment with regard to the vast amount of healthcare data that is generated in the UAE but not analyzed. However, he expressed confidence that post-COVID-19, there will be more government and private-sector spending in the sector to enhance its preparedness for future pandemics.

5.1.4. Customer Readiness

The findings of the interviews and survey show a relatively high customer (general public) readiness across all four readiness dimensions. The high motivational readiness is largely due to dissatisfaction with the services presently offered in the UAE healthcare sector. Most customers interviewed expressed a desire to see changes to existing services. The interviewees were unified concerns related to long wait times, improper diagnoses, and the interoperability of healthcare service providers. One interviewee stated, “even when I went to a different clinic within the same provider network, they didn’t have access to my medical records, which made diagnosis difficult.” Another respondent had similar concerns: “I lost all my medical records with my provider after they changed their software or application, any previous data they had was lost forever.” One interviewee highlighted that their pediatrician lost access to their children’s data when he switched jobs to another provider. Two respondents noted their displeasure with the insurance claims process. One remarked, “the insurance provider and the hospital will blame each other for the delay, and as customers, we are ones who suffer.” Some interviewees mentioned that they had experienced some form of data entry error with a healthcare service provider, either in their own profile or in the profile of a family member. Motivation readiness was reflected in the customer survey as well. For instance, 95% of respondents reported that they were concerned whether the medical products they were buying, especially medications, were original.

Regarding engagement readiness, when we explained to interviewees, in layperson terms, some of the benefits of blockchain, such as accurate electronic health records (EHR), data sharing, and interoperability, most expressed excitement and readiness to engage with these applications. One expressed a desire to

have their family health records data linked (with their consent), in order to understand patterns and vulnerabilities in their family health histories and enhance preventive measures. Others mentioned that these solutions (referring to EHR and patient data sharing) would improve the accuracy and usefulness of patient information, especially during emergencies such as road accidents. One respondent (along similar lines) highlighted the possible benefits accurate historical records would have provided regarding the ongoing COVID-19 pandemic, not just in the UAE but elsewhere. More than 85% of the survey participants mentioned that they had heard or had some understanding of blockchain and that they were willing to use/participate in blockchain networks.

The evidence from the customer survey showed high technical and structural readiness, in general, for new technologies. For instance, 86% of the respondents indicated that they would like to have ready access to their medical reports and tests. Also, 85% stated they would use blockchain or similar technologies to track the country of origin of products and their condition during transit through the supply chain. This was not surprising given that drug and product counterfeiting is a major concern in healthcare (Mettler, 2016).

5.2. Stakeholder Engagement in Blockchain Initiatives

The engagement (cooperation, collaboration, communication, and coordination) of stakeholders is critical for blockchain adoption. This includes exploring new opportunities together and working together during and after implementation to ensure project success. As elsewhere, stakeholder engagement is a challenge in the UAE. Concerns regarding the lack of stakeholder engagement are even greater for the healthcare sector. This is because, vis-à-vis other sectors, the sector has seen limited blockchain initiatives. Table 3 summarizes the key initiatives. More than half of the projects involved government entities. This reaffirms our findings that governments are key stakeholders responsible for driving blockchain initiatives in the UAE, including the healthcare sector. The evidence also indicates that except for two startup initiatives, all projects involved large firms. This supports our interview findings. Another concern is the lack of consortium or multi-stakeholder projects involving multiple hospitals, as witnessed in other sectors. Yet another concern is the lack of international collaboration or global blockchain partnerships.

Table 3. Key Blockchain Initiatives and Key Stakeholders Involved in UAE healthcare

Initiative	Description/Key Objectives	Key Stakeholders involved	References
Enhance electronic health records (EHR)	Application of Blockchain Technology to Electronic Health Records will benefit in collection and management of all the patients information within UAE in the most secure and reliable way	Hospital (NMC), Blockchain Solution Provider (GaurdTime) and Blockchain Solution Provider (Du)	(Du, 2017; US-UAE Business Council, 2018)
Sheryan smart licensing system	Deploy blockchain technology-based smart licensing system for licensing healthcare professionals looking to work in the UAE from anywhere in the world.	Governments (The Dubai Health Authority and Dubai Healthcare City Authority) and Customers (Doctors, nurses, pharmacists, and technicians)	(Dubai Health Authority, 2018)
Healthcare assessment system	Deploy blockchain-based system to save and share assessment information of health professionals with local licensing health authorities.	Government (Ministry of Health and Prevention) and Customers (Doctors, pharmacists, and technicians)	(MOHAP, 2019)
Patient Safety solution	UAE's first patients' blockchain-powered safety solution will make it easier for patients and healthcare providers to verify authenticity as well as the conditions of medicines.	Blockchain Solution Provider (Du) and Healthcare solution provider (Dhonor HealthTech)	(Zawya, 2019)
Hayat donor registry	The blockchain solution is intended at improving and securing organ donation. The platform will be used to register donors' pledge to donate organs.	Government (Ministry of Health and Prevention) and customers (Donors and receivers)	World Economic Forum (2020)
Blockchain-based platform for storing healthcare sector data	It is UAE's first advanced digital platform to store the data for health, pharmaceutical government and private facilities, health practitioners, and drug information.	Government (Ministry of Health and Prevention; Dubai Healthcare City) and all business entities (Hospitals, clinics, pharmacies, and laboratories)	WAM (2020)
Health and Wellness – 4P Solution	It's a UAE based health-tech startup company that utilizes a blockchain platform in 4P healthcare: Predictive, Preventive, Personalized, and Participatory. It captures vital health parameters to create personalized prevention programs for individuals, as well as to detect and monitor community and population health data.	Blockchain Solution Provider (BodyO) and Customers (general public)	DIFC (2019)
Contactless IRIS identification technology	It's a UAE based health-tech startup company that utilizes blockchain and biometrics-powered patient identification platform for contactless IRIS identification technology for secure and reliable patient data.	Blockchain Solution Provider (Liber Health) and healthcare providers	Emirates 24/7 (2020)

Challenges in stakeholder engagement were also evidenced during the expert interviews. One respondent stated: “Blockchain is not a private or single entity held technology, hence if you are planning to implement, then all the stakeholders should take the same step because each stakeholder has their own actionable part in it.” Most respondents highlighted issues relating to interoperability across healthcare entities. One interviewee gave an example that if a hospital in the UAE or elsewhere wanted to view patient data, they would be able to do so only after becoming part of the blockchain network. If other entities are not using blockchain or are not part of the destination entity blockchain, they cannot access or add to existing patient records on the blockchain of the destination entity, defeating the purpose of having a blockchain. One respondent highlighted the importance of stakeholders working together to achieve seamless connectivity or interoperability between independent blockchain platforms.

However, we can derive some positives. First, most of the blockchain projects that have been initiated are customer/patient-centric and have a direct, positive impact on people’s lives. For instance, the Hayat donor registry has been able to record the will of thousands of registered donors on their blockchain-based application. Participating hospitals can verify through the platform DNA matches of donors and recipients. This reduces organ trafficking. Similarly, the emergence of two promising blockchain startups, BodyO and Liber Health is encouraging enough to provide the impetus for other health-tech startups to use blockchain technologies. The relevance of the technology will be even higher in the wake of COVID-19 because healthcare providers are looking for solutions such as contactless biometric identification systems.

5.3. Facilitating Conditions

Various facilitating conditions of blockchain and their influence on the readiness of stakeholders are discussed in the following sections.

5.3.1. Regulatory and Policy Environment

While the UAE is making significant efforts to develop sound policies and a friendly regulatory environment for blockchain adoption, several concerns remain. According to the interviewees, “unclear regulatory expectation” is the topmost challenge for both business entities and blockchain solution providers. According to one respondent, “regulation in the UAE to date has considered blockchain as a crypto asset and therefore applies the same legal framework that is used to regulate cryptocurrencies.” Another respondent highlighted that their legal team was working hard to gain insights into the current regulatory framework governing blockchain technologies and that they were conducting internal assessments to ensure compliance. The response from the interviewee (a legal expert in fintech and blockchain) was that there is still no clear regulation of blockchain in the UAE in any sector, let alone healthcare and, therefore, concerns exist with regard to implementing smart contracts. Another interviewee highlighted a concern relating to a lack of consumer data protection laws specific to blockchain in the UAE. The interview findings are in line with a World Economic Forum report on lessons learned from the 200+ active blockchain projects in the UAE, which stated that the main challenge to blockchain deployment is regulatory issues (World Economic Forum, 2020). This accords with the

literature; governments are lagging in developing regulations to deal with technological innovations such as blockchain (Kimani et al., 2020).

5.3.2. Innovation Propensity

In general, in the UAE, significant efforts have been undertaken by governments to promote innovation as it is one of the six pillars of the national agenda. For instance, the UAE launched the National Innovation Strategy in 2014 and the National Strategy for Advanced Innovation in 2018. This was echoed in the interviews. According to the respondent from the government entity, blockchain is central to Dubai's "Paperless Strategy." The strategy aims to build an integrated paper-free government framework by the year 2021 and, in the process, eliminate more than a billion pieces of paper used for government transactions, including healthcare, every year (Smart Dubai, 2020b). Similarly, Dubai aims to become the first city to be fully powered by blockchain (Smart Dubai, 2020a). The establishment of the Global Blockchain Council is part of UAE government efforts to enhance UAE's position as a leading center for innovation and knowledge economy (Dubai Future Foundation, 2020). In line with national innovation strategies, the Ministry of Health and Prevention (MOHAP) has its own Innovation Health Strategy, the goals of which include creating advanced technology-based healthcare solutions (MOHAP, 2020). This innovation propensity of MOHAP has culminated in several blockchain projects (see Table 3). In the private sector, the proportion of SMEs investing in one or more innovation projects has almost doubled, from 29% in 2013 to 54% in 2019 (Dubai SME, 2019). Blockchain solution providers, especially large multinational providers such as IBM and Microsoft, are very innovative by nature, and therefore we expect to see more innovative blockchain proofs-of-concept and projects in the near future.

5.3.3. Privacy and Trust

Building trust among stakeholders is critical for the adoption of blockchain technologies. Overall, considerable progress has been made by the UAE government and business entities, in enhancing the privacy and trust of all stakeholders, especially customers. One interviewee highlighted the initiative of the Dubai Health Authority in implementing a smart contract that gives patients full control and ownership in approving the disclosure of their medical information to any stakeholder.

Despite progress, privacy and trust remain a concern in the UAE since the regulatory framework is at a nascent stage. This was echoed in the interviews. According to the government respondent, patient privacy is the main challenge for blockchain in the healthcare sector. The other concern highlighted by respondents (from a blockchain solution provider) is the lack of secure internet servers in the country as most data are hosted on third-party servers of blockchain solution providers in other countries. This was not surprising given the UAE's relatively low ranking (59^{th}) for "secure internet servers" in a global network readiness index survey (Network readiness index, 2019).

One interviewee (chief technology architect in a multinational hospital) mentioned the challenge in ensuring the security of patient data hosted in the blockchain. He said that if a patient has a chronic or terminal illness, they may not want everyone to see that they have this health problem. It is their responsibility as healthcare providers to ensure that patient data are not misused, especially given that it

is immutable. One legal expert mentioned the lack of clarity regarding the patient's right to have their data erased ('right to be forgotten') as mentioned in GDPR

Customers expressed even greater concerns. Customer interviewees explicitly expressed fears over "who gets access" to view their health data and "whether patient consent will be sought." A main concern for respondents was that governments and businesses could indirectly coerce their consent or make it mandatory for issuing visas or making job offers. Respondents mentioned that immutability would lead to more stringent audits and security checks on health conditions. In the words of an interviewee, "private healthcare consultations, especially with psychologists and psychiatrists, can be used against the patient, for example, in hiring decisions." Another mentioned that "patients who had a history of addictions and chronic illness could be disadvantaged and could even affect their employment status or even their legal residence status in the country." In sum, once a customer knew what blockchain is and how it works, concerns related to privacy and trust outweighed the benefits. They expressed the desire for complete control over what goes into the blockchain as immutable data as well as their voluntary consent (without any compulsion) regarding who is able to view the data.

5.3.4. Supporting Infrastructure

It was evident in this research that the UAE, especially during the past decade, has invested significantly in establishing a robust infrastructure to become a global leader in the adoption of the latest technologies and to develop a robust healthcare sector. Expert interviewees generally expressed satisfaction with the supporting infrastructure for blockchain adoption. According to one, the UAE government's liberal policies in attracting foreign investment, especially from developed countries, in the healthcare sector, will facilitate technology transfer, including blockchain technologies.

In addition, interviewees highlighted the role of tech startups and universities in promoting blockchain. It is encouraging to see the UAE government actively supporting tech startups through startup incubators and accelerators. For instance, the Dubai International Financial Centre's startup accelerator program is supporting six startup companies in blockchain, including one in healthcare. Similarly, in5 is a startup incubator based in Dubai, supporting several blockchain startups, including in healthcare (in5, 2020). UAE universities and global consulting firms have started offering training and certification programs in blockchain technologies, which will enhance the blockchain ecosystem. From a consumer perspective, access to 4G/5G internet encourages the use of blockchain applications. Also, the UAE is among the top per capita income countries, and customers thus have access to digital devices such as smartphones and laptops to support blockchain adoption.

6. Discussion

The validity of a framework is established qualitatively if the constructs and categories, explanations, and interpretations of the framework make sense. Specifically, findings should meet most of the requirements of framework validity such as credibility, transferability, dependability, confirmability, fairness, and authenticity to improve understanding, stimulate action, and empower action (Creswell & Miller, 2000).

Table 4 summarizes the blockchain readiness assessment findings for the UAE healthcare sector. It provides a snapshot of key findings related to the various components of the readiness framework. We were able to clearly organize the case study findings as per the components of the framework and provide adequate explanations regarding the blockchain readiness of the sector. A categorization of "Low," "Moderate," and "High" was used to summarize individual stakeholder readiness (governments, business entities, solution providers, and customers) and their collaboration readiness. The same categorization was used to capture the facilitating conditions influencing the readiness of stakeholders. The categorization provides a simple, generic understanding of blockchain readiness for relevant practitioners and policymakers devising policies and support mechanisms to address readiness-related differences.

The findings demonstrate the strong readiness of the UAE government in all four readiness dimensions. They affirm that the government is the most important stakeholder for driving blockchain initiatives and that they play multiple roles such as enablers, adopters, and regulators. However, the relatively low readiness of business entities, especially SMEs, in motivational and engagement readiness is a concern because over 90% of firms in the UAE and elsewhere are SMEs. If blockchain adoption does not happen inclusively, it will enhance the digital divide between SMEs and large firms, creating new inequalities or reinforcing existing ones. More support, education, and awareness are required to improve their engagement in blockchain projects. Successful use cases of SME blockchain projects will provide an impetus for other SMEs to explore blockchain solutions. Larger firms showed a greater propensity toward blockchain technologies and appeared to be in a much better position to leverage opportunities afforded by the technology.

The moderate to high readiness of blockchain solution providers across the readiness dimensions is encouraging, though their focus on healthcare is comparatively smaller vis-à-vis other sectors. Furthermore, the majority of blockchain solution providers are large nondomestic multinational firms. To promote local solution providers and startups, policymakers and industry groups could facilitate diffusion of innovation through collaborative partnerships such as international joint ventures and/or by non-domestic firms mentoring local firms and startups (Balasubramanian & Shukla, 2020). The relatively high customer readiness across all four readiness dimensions is encouraging, given that their willingness and ability to participate in the blockchain ecosystem are critical to its widespread adoption.

Table 4. Summary of Blockchain Readiness Assessment of UAE healthcare

Readiness		Government	Business Entities	Blockchain Solution Providers	Customers
Individual Stakeholder Readiness					
Motivational Readiness	→	**High** • UAE Vision 2021 aims to achieve a world-class healthcare sector • Dubai Healthcare strategy aims to transform Dubai into a leading healthcare destination • Abu Dhabi Healthcare Strategic Plan seeks to improve the quality of healthcare services, patient safety, and experience as well develop E-Health program	**Low** • In general firms, especially SMEs are not up-to-date with key contemporary technologies and trends • Many small firms have not heard of 'blockchain.'	**Moderate to High** • Solution providers and consulting firms are trying to change the status quo of business entities towards blockchain implementation • Focus on healthcare solutions is still limited	**High** • Customers want to see improvement in existing practices/ services • Dissatisfaction with long waiting times, improper diagnosis, data entry errors, and importantly interoperability
Engagement Readiness	→	**High** • Launch of UAE Blockchain Strategy 2021 • Launch of Dubai Blockchain Strategy • Start of Global Blockchain council	**Low** • Lack of knowledge and awareness • Lack of clarity on regulatory issues	**Moderate to High** • More than 120 blockchain companies in the UAE • Several blockchain start-ups • More than 200 active projects but few in healthcare • Healthcare specific blockchain firms are limited	**High** • Keen awareness of and willingness to engage with blockchain technologies • The desire for supply chain traceability of medicines/products and country of origin
Technical Readiness	→	**High** • Leverage technological innovation through the Smart Dubai 2021 initiative • Exploit disruptive innovation through Dubai 10X initiative to become ten years ahead of other world cities • Ranked first in the world in government procurement of advanced technology products	**Moderate to High** • Most firms use the latest Information and Communication Technologies	**Moderate to High** • All major global blockchain providers are active in the UAE (e.g., Microsoft, SAP, IBM, Amazon, etc.) • Support for start-ups • Availability of wireless and cloud infrastructure, faster connectivity and higher bandwidth • Set to leverage 5G networks	**High** • Availability of technological resources such as smart devices, computers, tablets, and smartphones • Availability of mobile and home internet for anytime and anywhere access to health records and services

Readiness		Government	Business Entities	Blockchain Solution Providers	Customers
Structural Readiness	→	**High** • The government is the biggest spender in the healthcare sector at approx. $10 billion • The strategic partnership between Abu Dhabi Health Services Company and LinkedIn	**Moderate to High** • A significant increase in IT budget among firms. • Most firms have dedicated IT budget	**Moderate to High** • All major global blockchain providers have strong financial and human resource backing as well as worldwide R&D divisions • Healthcare division is lacking in most major firms	**High** • High per-capita income to afford the technology • Strong familiarity and expertise in using various technologies
Stakeholder Collaboration Readiness (Based on Table 3)					
Government	↔	**Moderate to High** • Evidence of cooperation/ collaboration between different government entities (e.g., The Dubai Health Authority and Dubai Healthcare City Authority; Ministry of Health and Prevention and Dubai Healthcare City)	**Low** • Only evidenced for a blockchain-based platform for storing healthcare sector data	**Low** • No direct evidence from the case study	**High** • Evidence of direct collaboration (e.g., Sheryan smart licensing system; Healthcare assessment system; and Hayat donor registry
Business Entities	↔	-	**Low** • No direct evidence from the case study	**Moderate to High** • Evidence of collaboration witnessed (e.g., for electronic health records; and contactless IRIS identification technology)	**Low** • No direct evidence from the case study
Blockchain Solution Providers	↔	-	-	**Moderate to High** • Evidence of collaboration witnessed (e.g., for electronic health records; and patient safety solution)	**Low** • Only evidenced for BodyO, the health-tech startup firm
Customers	↔	-	-	-	**Low** • No direct evidence from the case study
Facilitating Conditions Readiness					
Regulatory and Legal	→	**Low** • Launch of Dubai Blockchain Policy is promising, but there is no	**Low** • High stakeholder concerns related to blockchain regulatory and legal environment • Concerns related to the validity of smart contracts		

Readiness		Government	Business Entities	Blockchain Solution Providers	Customers
		federal-level blockchain policy and regulation • Blockchain considered under the legal framework of cryptocurrencies	• The regulatory issue emerged as the top challenge in the world economic-forum report of UAE blockchain projects		
Innovation Propensity	→	**High** • Innovation is one of the six pillars of the UAE national agenda • Established the National Innovation Strategy in 2014 • Launched National Strategy for Advanced Innovation in 2018 • Dubai government's Paperless Strategy 2021 • Launch of Center for Fourth Industrial Revolution • Launch of Innovation Health Strategy	**Moderate** • Large firms found to be more innovative than small firms • SME innovation almost doubled from 29% in 2013 to 54% in 2019.	**Moderate to High** • Most large multinational blockchain providers such as IBM, Microsoft, Amazon have high innovation propensity • Limited evidence regarding small and medium blockchain providers • Few blockchain start-ups in healthcare are very innovative (e.g., Body0, Liber Health)	**Moderate to High** • Customers, in general, have demonstrated innovation propensity in using smart devices, smart payments gateways, etc.
Privacy and Trust	→	**Moderate** • Most initiatives are in the planning phase such as consent and data privacy frameworks to protect patients' data, and smart contract, which gives the patient the full control and ownership of their health data	**Low** • Concerns related to the privacy of patient data • Lack of secure internet servers in the UAE • Lack of consumer data protection law specific to blockchain • Concerns related to the incompatibility of UAE blockchain regulations and GDPR		**Low** • Strong concerns expressed by consumers related to the misuse of data by business and governments
Supportive Infrastructure	→	**High** • Established free zones to attract leading global healthcare providers • Strong support for startup incubators and accelerators • Availability of University programs, training and certification programs in blockchain in the UAE • Robust IT infrastructure of the UAE			**High** • Free Wi-Fi for public • Availability of Smart Kiosks • Internet and mobile coverage throughout the country • Availability of 5G networks

Regarding stakeholder collaboration readiness, government entities have shown strong readiness to collaborate with other government entities. Unfortunately, only limited evidence of public-private partnerships, multi-stakeholder consortium projects, and international collaboration was available. Enhancing government collaboration with business entities and blockchain solution providers is critical to facilitating complementary knowledge and skill acquisition for innovative blockchain solutions. However, it was encouraging to identify several customer-centric blockchain projects initiated by public sector entities. This shows that the UAE public sector is answering calls in the literature to implement patient/customer-centric blockchain solutions (Dimitrov, 2019; Siyal et al., 2019). Overall, difficulty in bringing different stakeholders to the table for blockchain initiatives remains the topmost challenge for blockchain adoption. This is in line with previous findings that intra- and inter-stakeholder collaboration issues are a significant barrier to blockchain adoption in the healthcare sector (Dhagarra et al., 2019).

In terms of facilitating conditions, customer concerns related to privacy and trust remain a prominent issue requiring immediate attention. The evidence points to a need for customer-first, privacy-first blockchain solutions that give customers full ownership and control over their data. The general public should also clearly see the full benefits of participation, especially solutions with the potential to positively impact people's lives. Hence, educating and creating awareness of the benefits of blockchain and addressing concerns regarding privacy and trust are critical for public participation. Similarly, addressing the privacy and trust concerns of business entities and blockchain providers, such as those related to secure internet servers and GDPR, is important. In response, the UAE government is making efforts to increase the number of local servers. Leading blockchain solution providers such as IBM, Microsoft, and Amazon have recently opened a state of the art data centers in the UAE to support their blockchain and cloud solutions (The National, 2020). The UAE Center for the Fourth Industrial Revolution is working with key stakeholders in the healthcare and public sector to co-develop consent and data privacy frameworks to protect patient data (C4IR, 2020).

Lack of clarity on blockchain regulations and laws such as those regarding consumer data protection and the legal validity of smart contracts are pressing concerns holding back firms from implementing blockchain solutions (Kimani et al., 2020). For example, tensions surrounding whether data should be mutable or erasable should be addressed upfront before any blockchain solutions are implemented. From a regulatory and legal perspective, it is important that appropriate policy measures be in place to enable individuals and businesses to benefit from blockchain technologies. However, a balancing act is required when developing the policy framework, which should be neither too restrictive nor too lax. It should be capable of supporting the appetite for innovation of the sector and the country but not compromise on the potential downside/unknown risks of the new technology, thereby protecting the interests of all stakeholders. Previous studies have highlighted that unregulated innovations might pose hazards in the conduct of business (Kimani et al., 2020).

A strong readiness to innovation was witnessed across stakeholders. Again, the public sector is leading the way in promoting an innovative culture in the UAE. For example, public sector innovations such as paperless Dubai have paved the way for blockchain adoption. Similarly, supportive and robust infrastructure such as ICT infrastructure and the establishment of economic free zones to attract outside firms and investors were found to have been critical in supporting the adoption of emerging technologies

such as blockchain. The other key finding in terms of supporting infrastructure is the support extended to startups by governments and other stakeholders, such as with the establishment of innovation hubs and accelerators programs. These are vital to sustaining the growth of blockchain technologies.

Overall, Table 4 confirms the validity of the framework. It shows that the framework is credible and can be applied in any research setting to assess the blockchain readiness of the healthcare sector.

7. Conclusions

Only a few years have passed since the world realized the disruptive potential of blockchain in areas other than cryptocurrencies. While anecdotes and use cases about the impact of this technology abound, sectors and countries have shown varied readiness toward its adoption. Yet, no comprehensive evidence-based and structured approach has been made to understanding this readiness. A comprehensive, multi-dimensional blockchain readiness assessment framework with the potential to be applied to any sector or country context was developed in this study. The usefulness and applicability of the framework was demonstrated in a real-life setting through a case study of the UAE healthcare sector. In the process, the authors answered several pressing research questions that have implications for the adoption of blockchain technologies.

The implications of this study are manifold. For its research implications, the authors were able to identify and integrate various isolated components into an empirically tractable and meaningful readiness assessment framework. Key stakeholders, their extent of readiness, and their readiness to collaborate with other stakeholders were understood. The key facilitating conditions necessary for the widespread adoption of blockchain, such as infrastructure, privacy, trust, regulatory/legal aspects, and innovation propensity, were identified. This is the first investigation of blockchain in the UAE healthcare sector, and the findings are, therefore, both novel and significant.

In terms of practical implications, this research demonstrates that blockchain has enormous potential to transform healthcare sectors. From managing patient data to tracking drugs through the supply chain, blockchain could solve pressing problems in the industry. Also, the case study findings are relevant for other countries, especially for those that share a vision similar to UAE; to become a global leader in providing world-class health services as well as open to disruptive technologies such as blockchain.

With regard to societal implications, we found both positive and negative implications. Positive implications include that blockchain can be effectively utilized in countering fake drugs and medical equipment, thereby saving lives. Patient-centric blockchain solutions have the potential to enhance precision medicine, biomedical research, genetic engineering, and other advancements. Importantly, individualized, life-long patient care data stored on the blockchain can be easily shared digitally. It also facilitates real-time and remote patient care, which is critical for many patients. Further, applications of blockchain such as smart contracts help reduce the use of paper, related travel, and couriers, thereby supporting the environment. However, data-related privacy and security are some of the societal concerns surrounding blockchain. Many patients wish to keep their treatment private, and concerns/fears related to who has access to their health data and whether it will be misused need to be addressed.

The study has some limitations. Although the proposed framework was developed based on an extensive review, it may not cover every facet critical for blockchain adoption. Also, the application of the framework was tested only in one sector in a single country. Furthermore, the application was demonstrated through a predominantly qualitative approach, and therefore statistical/quantitative precision validating the framework is missing. Finally, though the results are generalized for business entities, insights were obtained mostly from hospitals/clinics. Given that several other entities come under the umbrella of "business entities" in the framework, such as pharmacies, insurance providers, health research centers, drug, and equipment manufacturing companies, among others, more in-depth investigation is required to delineate nuances in the readiness of various entities.

For future research, given the conceptual comprehensiveness and generic nature of the framework, researchers in different industrial settings could adapt and use the framework in their respective contexts; healthcare represents a myriad of sectors, such as manufacturing (drug and medical equipment), services (e.g., insurance, transportation-ambulatory) and research and development (e.g., clinical trials, laboratory experiments). Its potential applicability to other sectors is therefore high, provided applications are carefully crafted and contextualized. Furthermore, future research could apply more rigor in their primary investigation and potentially conduct a large-scale survey-based study to test the statistical appropriateness and generalizability of the framework in different settings. Moreover, given that blockchain in healthcare is a relatively new and promising domain, future studies could attempt to strengthen the proposed framework through refinement and validation across countries and test its usefulness and applicability in different settings and sectors.

Despite these limitations, we believe the proposed framework and its successful application will significantly enhance understanding of blockchain in the healthcare sector. We anticipate that this study will encourage more research on blockchain in healthcare and other industries and will contribute to theoretical advancement in the field.

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