# Modeling the enablers of blockchain technology implementation for information management in healthcare supply chains

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## Abstract

**Purpose** – Blockchain technology enhances information management in healthcare supply chains by securing healthcare information and providing medical resource traceability. However, there is no decision framework to support blockchain implementation for managing information, especially in emerging economies' healthcare supply chains. This paper develops a hierarchical decision model for implementing blockchain technology for information management in emerging economies' healthcare supply chains.

**Design/methodology/approach** – This study uses 20 health supply chain experts in Ghana to rank 17 decision criteria for implementing blockchain for healthcare information management using the best-worst method (BWM) multi-criteria decision technique.

**Findings** – The results show that "security" and "privacy," "infrastructural facility" and "presence of training facilities" are the top three critical factors impacting blockchain adoption in the health supply chain for healthcare information management. Other sub-factors are prioritized.

**Practical implications** – To implement blockchain effectively to enhance information management in the healthcare supply chain, health institutions, blockchain technology providers and state authorities should concentrate on the highly critical factors extracted from the study.

**Originality/value** – This is the first study that develops a hierarchical decision model for implementing blockchain technology in emerging economies' health supply chains.

**Keywords** Healthcare information management, TOE, Blockchain technology, Best-worst method, Emerging economies

**Paper type** Research paper

## 1. Introduction

Cost control has driven healthcare organizations to make supply chain management (SCM) a critical phenomenon to achieve the organization's objectives. SCM involves the flow of products, finances and information within and between actors to meet consumers' needs effectively. Effective SCM is a challenge in the health industry.

The inherent risk of errors in the supply chain exposes patients to many dangers. The situation is more alarming as there are increasing reports of violations of healthcare



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information, information asymmetry and counterfeit medicines in the health industry (Hadid *et al.*, 2022). For instance, the global market loses up to $200bn annually to the fake medicine market (Knudsen and Nickels, 2015).

Studies have discovered a host of medications, medical devices and biologics prone to counterfeiting in several countries. In Africa, more than 100,000 die from counterfeited medicines (Glass, 2014). Besides counterfeiting products and medicines, product recording and packaging mistakes can disrupt the health supply chain.

Many health experts describe information asymmetry as the most critical issue in the healthcare supply chain (Chang *et al.*, 2023). Information asymmetry means that one side has greater access to information than another. This issue is crucial when only doctors or health centers can access the records of patients in general healthcare. The data is centralized in a single health system and only hospitals or associations have access. As a result, patients need to follow complicated and complex protocols to access their medical records. This situation often leads to medical data abuses in the healthcare sector.

As technical advances have improved conditions in many other aspects of life, applying them to enhance healthcare delivery is also essential. Blockchain is one of those emerging technologies. There have been many applications of blockchain technology to solve problems of traceability and security in many sectors.

In the healthcare supply chain, blockchain technology can provide information visibility to enhance patient safety (Sharma *et al.*, 2023). It also addresses issues relating to traceability and allows for safe interoperability across health organizations. However, most health practitioners underestimate the blockchain and its application to the healthcare supply chain. Therefore, it is highly appropriate for practical perspectives and a deep understanding of major enablers, making it easier for the industry to implement blockchain technology successfully.

Although much literature on blockchain technology benefits exists in many sectors, little is known about its health-related disruption, particularly for information management in emerging economies' healthcare supply chains (Kombe *et al.*, 2019; Quayson *et al.*, 2023b). In few existing studies, Attaran (2022) conducted a literature review to discover the pivotal roles blockchain technology plays in solving some of the most critical and challenging issues facing the healthcare industry. The study identified challenges and opportunities for implementing blockchain technology in healthcare supply chains and summarized health-related blockchain products and key players offering solutions across different applications. Also, Ndayizigamiye and Dube (2019) presented a case for using blockchain to foster transparency and accountability in patient-centered care in South African public healthcare institutions.

Despite the relevance of prior studies, they are primarily reviewed and conceptual with little theoretical development. Again, the health supply chain has no decision-making structure regarding blockchain adoption for healthcare information management, particularly in emerging economies with a slow pace in blockchain technology adoption and usage (Quayson *et al.*, 2023b). Blockchain adoption requires a careful decision-making tool to aid such a decision-making process. Therefore, a multi-criteria decision-making methodology must provide a decision structure to incorporate blockchain technology in the emerging economies' health supply chain.

Theoretically, the technology-organization-environment (TOE) framework provides an appropriate lens for studying blockchain adoption at the organizational level. This study identifies a list of enablers that affect blockchain adoption for health information management in the health supply chain based on the TOE framework. In addition to the technology, implementing technical innovation is based on internal environmental and organizational considerations. Several organizational technology implementation studies (e.g. Kamble *et al.*, 2021; Bai *et al.*, 2022) have used the TOE framework. The high application

of the TOE framework in explaining and analyzing technological adoption inspired its adoption for our study.

The paper highlights the literature gaps for blockchain by drawing on existing adoption research to develop a decision framework for blockchain implementation for healthcare information management in the health sector. In Ghana, the health sector can use insights into the crucial factors in blockchain adoption to improve health information management to achieve competitiveness. Research into new contexts, especially in emerging economies like Ghana, is recognized as crucial guidance in research on potential technology adoption. Moreover, the socio-economic effect of the Ghanaian health sector on the nation is substantial and is still under-investigated.

Ghana's Health sector's socio-economic cost is high because of the massive demand for quality healthcare to achieve United Nations (UN) Sustainable Development Goal-Three. As a consequence, this paper contributes by;

Firstly, introducing a hierarchical decision structure that builds upon the TOE framework to guide the decision-making process for incorporating blockchain technology in healthcare information management. This structure enables healthcare organizations to assess and address various dimensions and levels of decision-making, ranging from strategic considerations to operational implementation (Gongora-Salazar *et al.*, 2023).

Secondly, the paper contributes by adapting the widely recognized TOE framework to the context of healthcare information management and the health supply chain. By incorporating the TOE framework, the study provides a comprehensive perspective that considers the technological, organizational and environmental factors influencing the successful adoption and implementation of blockchain technology in Healthcare (Effah *et al.*, 2023).

Thirdly, the study focuses on the health supply chain, acknowledging this domain's unique challenges and requirements. By considering the flow of healthcare information within the supply chain and the potential benefits of blockchain technology in enhancing data integrity, traceability and transparency, the paper contributes to understanding blockchain's specific applicability and implications in this context (Quayson *et al.*, 2023b).

The study achieved these results by thoroughly reviewing relevant literature to identify the enablers. These experts in the Ghanaian health sector evaluated the enablers using best-worst method (BWM) designed questionnaires. The feedback from these questionnaires was analyzed using the BWM Solver to prioritize the enablers of blockchain adoption in the health sector. The BWM model gives more consistent results than other multi-criteria decision methods (MCDM), which use pairwise comparison (Rezaei, 2015). Again, the BWM is easier for pairwise comparisons than analytical hierarchy process (AHP) (Bai *et al.*, 2022). These influenced our choice of the BWM MCDM technique.

The paper continues as follows. Related works are presented in Section 2. Section 3 presents the research methodology. Section 4 presents and discusses the results. Finally, Section 5 presents the conclusions of the study.

## 2. Related works

### *2.1 Blockchain and healthcare information management*

Blockchain technology has the potential to significantly impact information management in healthcare supply chain by enhancing security, interoperability and data integrity (Effah *et al.*, 2023). The blockchain is a decentralized and encrypted database, a permanent, incorruptible digital information archive. Blockchain technology records all transactions authenticated by the parties involved, so only approved parties can use these records. The confidentiality and data integrity of transactions without the intervention of third parties is one of the major reasons for using blockchain technology. Besides, blockchain technology offers a continuous audit path to see participants' time and actions. This improves

transparency and lowers the risk of health information manipulations. Blockchain technology also ensures real-time data availability, contributing to better coordination of clinical care and improved health administration.

Research into blockchain technology in the health supply chain is a rising research stream, especially regarding information management. Esmaeilzadeh and Mirzaei (2019) investigated the potential of blockchain technology for information management in the healthcare supply chain from patients' perspectives. They found significant differences in patients' perceptions of various information exchange mechanisms about patient privacy concerns, trust in competency and integrity, opt-in intention and willingness to share information. Similarly, Esmaeilzadeh (2022) applied a qualitative technique to explore the benefits of blockchain-based health information exchange (HIE) in the healthcare supply chain from physicians' perspectives. The NVIVO analysis categorized the benefits into three themes: innovative technological features, collaborative ecosystem and system performance.

Furthermore, Hajian *et al.* (2023) designed an empirical study for blockchain-based information-sharing systems in electronic health records. The results revealed that blockchain-based information systems could empower patients by providing the perception of control over their health records. Blockchain technology motivates patients to share information with healthcare provider systems and has the advantage of reducing healthcare costs and improving diagnosis management.

Also, Pawar *et al.* (2022) proposed eHealthChain – a blockchain-based Personal Health Information Management System (PHIMS) for managing health data originating from medical Internet of Things (IoT) devices and connected applications. They argued that for usability and wide acceptance, the PHIMS should follow the design principles that guarantee privacy-aware health information sharing, individual information control, integration of information obtained from multiple medical IoT devices, health information security and flexibility. Again, Elvas *et al.* (2023) proposed adopting a blockchain framework to enable the transparent sharing of medical information among health entities in a secure environment. The patient-centric approach may allow hospitals and health professionals' access to their data.

Moreover, Randall *et al.*, (2017) explored blockchain applications and use cases in health information management in the USA. They suggested that blockchain can potentially cause issues with health information management. They argued that a public program such as the US Medicaid program, with US$553bn in total program costs and over US$25bn spent on health information technology and administration last fiscal year, could benefit from using blockchain-based distributed ledger and smart contracts. They further posited that a decentralized benefits administration system could provide greater efficiency to enrollment, eligibility, claims payment and adjudication processes, thus driving efficiency and reducing systemic fraud.

Ibor *et al.* (2023) proposed a secured health information system with blockchain technology in Africa. The proposed system on a blockchain could create a trust-free system for both health personnel and patients, achieving the decentralization of the medical records database to enhance the security and privacy of data on the modeled peer-to-peer network.

Notwithstanding many previous related studies, significant gaps in the literature still need to be addressed. Firstly, most of these prior works (e.g. Pawar *et al.*, 2022; Elvas *et al.*, 2023) focus on advancing system design to blockchain technology for information management in the healthcare supply chain, neglecting its implementation plans. The effect would be less important if the blockchain framework for information management in the healthcare supply chain is built without implementation plans.

Also, although past studies have portrayed blockchain as a fundamental technology for future supply chains, these studies are generally hypothetical. There is a limited practical application for blockchain technology. Again, these studies do not provide much empirical

evidence on blockchain implementation for information management in emerging economies' health supply chains, especially in Ghana (Quayson *et al.*, 2020). Abekah -Nkrumah *et al.* (2014) empirically illustrated the impact of contextual variables on implementing ICTs in the health supply chains in Ghana. Emerging information technology in the health supply chain in Ghana is still in the new stages. This is because of the perceived high investment costs of advanced technology and the lack of infrastructural facilities for information technology (IT) technologies.

Moreover, most previous studies suffered theoretical limitations as a basis for blockchain adoption analyses in the health supply chains for information management (Khan and Mir, 2019). To address these gaps, we use Technology, Organizations and Environment (TOE) as our basis to provide a robust theoretical framework that includes incentives for innovations. A theoretical research modeling technique helps address these gaps effectively. We employ the BWM MCDM technique in the modeling method. BWM has several essential features (Rezaei, 2015). We have provided justifications for the BWM technique and will provide detailed information later. The modeling process assures the management of the successful use of blockchains and provides insights into what to think. This study offers research implications to help health professionals incorporate blockchain technology for data protection and operational efficiency.

### *2.2 Blockchain characteristics relevant for healthcare information management*

Blockchain technology has several characteristics that make it relevant for healthcare information management. These characteristics address various challenges in healthcare data security, interoperability and integrity. We discuss some of these characteristics.

*2.2.1 Anonymity and privacy.* A privacy-preserving framework is built into the blockchain to protect patient healthcare information privacy, with options for private transactions, zero-knowledge proofs and selective data sharing. The blockchain provides the deployment of a cryptographic private key that guarantees such information privacy and anonymity. Because blockchain uses ring signatures, users are protected by anonymity. A ring signature is an encryption that checks to see if the person signing the message, one of the stakeholders, holds a private key corresponding to a unique set of public keys without telling which one it is. The self-sovereign identity with blockchain effectively maintains the privacy of patient health information. This feature enables patients to own, control and manage their health information, as shown in Figure 1.

*2.2.2 Auditability.* One of the most striking features of blockchain for healthcare information management is that it is auditable. Blockchain provides a trust-free, tamper-proof and automated system that can be traced securely and permanently. Distributed databases are made fault-free using a blockchain, keeping an audit trail. The integrity of all transactions is auditable to all participants, with conforming verification of trust. Blockchain implementation across healthcare supply chains will ensure healthcare information integrity and trustworthiness (Gruchmann *et al.*, 2023).

*2.2.3 Smart contracts.* An asset or information is digitally transferred into a blockchain application in a smart contract (Lynberg and Deif, 2023). A smart contract, a stored set of rules that apply to network actors and the system, can help define network interaction. Network data sharing among supply chain participants and continuous process improvement are all possible because of smart contracts. Product and actor profiles are associated with digital representations on the network, where users can see additional information, such as a location, certificate, or endorsement. By logging in the key information of a given product and its status on the blockchain network, each supply chain player can access this information.

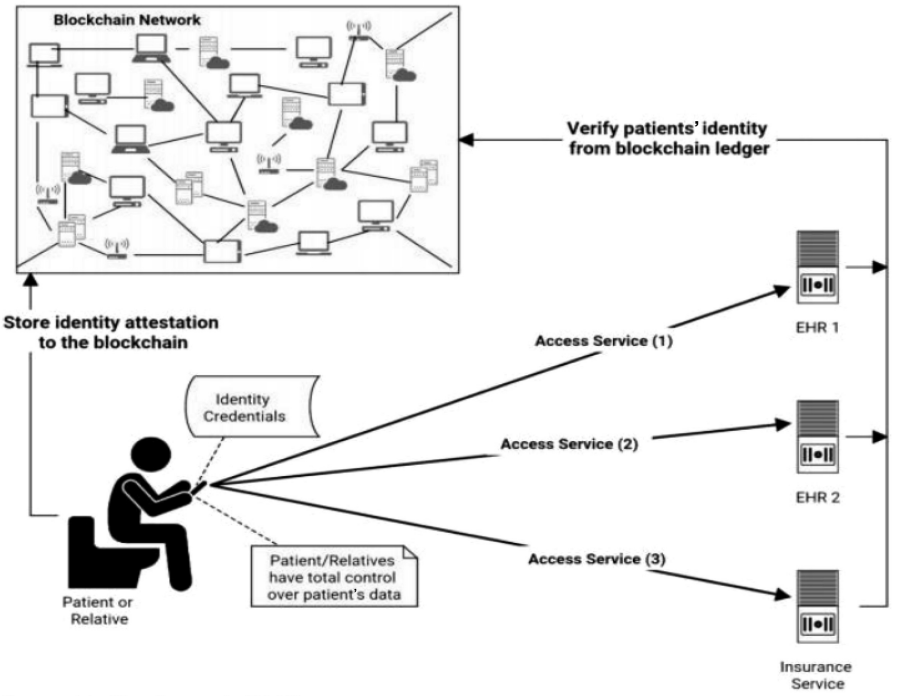


**Figure 1.**
Self-sovereign identity with blockchain in the health sector

**Source(s):** Kombe *et al*. (2019)

Smart contracts can automate healthcare information flows, such as insurance claims processing, appointment scheduling and prescription management, reducing administrative overhead and improving efficiency. Since all health supply chain participants must have a consensus to conduct information exchanges, they must first agree on their parameters. A smart contract is advantageous because it holds the participants' terms in agreement. In a blockchain-based supply chain, smart contract governance and process certification rules can control who is certified, what they are certified for and who can approve and execute their orders.

*2.2.4 Secured database.* A blockchain database is distributed. The advantage of blockchain technology's asymmetrical cryptography is that it uses hash and block exchange validation, making it highly secure. It is difficult to manipulate the data stored on a block in the ledger. There is a strong argument in favor of using the secure database feature in helping intelligent organizations. Due to blockchain's advanced cryptographic techniques to secure data, it ensures that healthcare information is stored and transmitted securely, reducing the risk of data breaches and unauthorized access (Attaran, 2022).

*2.2.5 Immutability.* Immutability is a term used to describe a thing's inability to be changed over time or its consistency over time. Blockchain's registry contains an audit trail that keeps track of all the operations performed, which helps determine the authenticity of records. Because of the blockchain's inherent immutability, its networks are less vulnerable to data manipulation and forgery via cyberattacks. Therefore, once health information is added to a blockchain, it cannot be altered or deleted without consensus from the network, ensuring the integrity and authenticity of healthcare records.

*2.2.6 Decentralized database.* Data communication metadata is distributed across the ledger in a blockchain, as a blockchain database is not centralized. The data is distributed simultaneously on various nodes. The decentralized and distributed nature of the blockchain technology database allows for a decentralized ecosystem. This enhances participants' trust in the blockchain. If healthcare information is stored in this decentralized ledger, it reduces the reliance on a single central authority and makes the system more robust against single points of failure. Also, patients can have more control over their healthcare information, granting access only to authorized parties through consent mechanisms.

*2.2.7 Traceability.* Blockchain can trace the sourcing, processing, sharing and transferring of accurate data. Information in any form can be tracked down to the date and time of each block on the blockchain using the timestamp. All blockchain has to do is ensure a secure, shared database and that every transaction is transparent and traceable. Blockchain records a transparent and immutable audit trail, allowing healthcare providers and patients to trace the history of health data access and modifications.

2.2.7.1 Transparency. A virtual copy of the blockchain network is generated at each node, allowing real-time auditing and data inspection. The most significant benefit of transparency in the various network operations and activities is removing the need for a trusted intermediary. Blockchain technology can help build trust and credibility by fostering transparency in health information management. For blockchain, rebranding the network's reputation is a new frontier in redesigning the network and combatting fraudulent activities. The level of authenticity in the blockchain is high, resulting in more information transparency. Depending on privacy and regulatory requirements, healthcare organizations can choose between public or private blockchains to control who can access the data while maintaining transparency within the network.

*2.2.8 Dentifying blockchain adoption enablers.* We use the theoretical TOE lens to consider different factors influencing blockchain technology implementation across the health supply chain in emerging economies. The TOE is a widely defined theoretical context for technical advancement. The TOE asserts that the technical (T), organizational (O) and environmental (E) contexts are three major components that shape technology usage (Shiau *et al.*, 2023). The TOE can be applied to blockchain adoption because blockchain is a new technical creation. Thus, we developed our theoretical framework based on the critical environmental, technological and organizational factors that directly affect the implementation of blockchain technology in the health sector.

*2.2.9 Technological factors.* Technological factors concentrate on how blockchain technical features enhance data protection and operational efficiency in the health supply chain (Wolff and Madlener, 2019). The availability of specific blockchain resources, such as smart contracts, is essential for improving performance in the health industry. The infrastructural facility is another significant enabler influencing blockchain adoption in the health supply chain. Infrastructure facilities include physical elements and software elements. The infrastructural facilities support current infrastructure requirements (Darko *et al.*, 2023). Another technical issue is the complexity of blockchains, which require specific skills to make their adoption easier. The ease of use is also a significant factor that affects the implementation of blockchain technology in the health sector (Tripathi *et al.*, 2020). Compatibility is also a key factor in this context. It describes the easy integration of blockchain technology with other platforms. This identifies the expected value that blockchain technologies bring to the health sector. Moreover, information protection and privacy are vital technological enablers (Raza *et al.*, 2019). It ensures the security of shared information to prevent exploitation while adopting blockchain-related healthcare technologies.

*2.2.10 Organizational enablers.* The organizational factor defines the features, functionality and tools that promote or prevent blockchain technology adoption in the

health sector. Firstly, training facilities are an essential organizational factor (Kushwaha and Talib, 2020). This provides sufficient training facilities for workers in the health sector to adopt blockchain technologies. Top Management support is also essential. Top managers can provide advice, services and necessities during and after blockchain technology acquisitions in the health sector. Furthermore, organizational culture consisting of the actions and practices of people within health institutions affects the implementation of blockchain technology. The organizational factor also affects perceived investment costs, including access to finances for substantial capital investments while implementing blockchain resources in the health industry. The capacity of human resources is also vital in ensuring health professionals provide the know-how to use the technology.

*2.2.11 Environmental context.* This refers to business-based operating factors, like government regulations, competitive pressure, market volatility and pressure on stakeholders. Competitive pressure describes an ongoing desire for health institutions to display customer or investor competencies (Wong *et al.*, 2020). Competition, globalization and expenditure have driven health facilities to develop and boost their competitive advantage. Also, Government policies and funding often influence the capacity to enforce regulations and rules that facilitate blockchain adoption in the health sector by relevant government agencies (Yavuz *et al.*, 2023). The burden on the external environment is also crucial to stakeholders and details the extreme and constant demands of various actors or health investors. Companies typically respond to market demands on innovation differently. Therefore, market instability or inherent health services volatility can affect the adoption of the health sector blockchains.

Table 1 provides a summary of the blockchain adoption enablers.

## 3. Methodology

As shown in Table 1, implementing blockchain technology is a multi-criteria concept. Therefore, we use MCDM to assess the various criteria. This study uses the BWM process, which was previously not used in this field but has specific benefits for this paper.

**Table 1.** Blockchain adoption enablers in the health supply chain

| Main enabler | Sub-enablers | References |
|---|---|---|
| Technological (TEC) | Compatibility (TEC1)<br>Security and privacy (TEC2)<br>Immutability (TEC3)<br>Infrastructural facility (TEC4)<br>Access to blockchain technology and tools (TEC5)<br>Ease of use (TEC6)<br>Perceived benefits (TEC7) | Raza *et al.* (2019) and Bai *et al.* (2022) |
| Organizational (ORG) | Capacity of human resource (ORG1)<br>Organizational culture (ORG2)<br>Top management support (ORG3)<br>Perceived cost of investment (ORG4)<br>Presence of training facilities (ORG5) | Schumacher *et al.* (2016) and Kushwaha and Talib (2020) |
| Environmental (ENV) | Market uncertainty (ENV1)<br>External stakeholder (ENV2)<br>Competitive pressure (ENV3)<br>Government policy and support (ENV4)<br>Industry involvement (ENV5) | Hanif *et al.* (2018) and Wong *et al.* (2020) |

**Source(s):** Authors' own work

*3.1 Best-worst method*

The BWM is designed to solve MCDM problems and draw on a contrast between them. BWM has two significant advantages over other MCDM approaches. Firstly, compared to a complete matrix, it needs fewer comparison data. Secondly, BWM provides more consistent results than other MCDM methods that use the complete pair comparison matrix. As a result, the technique has many applications in solving different problems in the real world. For instance, Bai *et al.* (2022) applied it to develop a hierarchical enablers framework for improving sustainable supply chain transparency (SSCT) by blockchain technology in the cocoa industry. Again, Tuffour *et al.* (2022) used it to evaluate data from 150 managers on government policies' effectiveness to quicken SMEs' operations amid COVID-19 in Ghana. This study uses the previously unused BWM process in this field but has specific benefits for this paper.

Razaei (2016) (Rezaei, 2016) structured the BWM process as follows:

(1) Decision-makers determine a set of criteria $C = \{c_1, c_2, \cdots c_n\}$.

(2) Decision-makers identify the best criterion and the worst criterion.

Decision-makers compare the best criterion to others on a 1-9-point scale. A score of 1 represents an equal preference between the best criterion and another criterion. Also, a score of 9 shows an extreme preference for the best criterion over another criterion. The outcome gives the Best-to-Others (BO) vector as: $BO = \{a_{B1}, a_{B2}, \cdots a_{Bn}\}$. $a_{Bj}$ depicts the preference of the best criterion $B$ over criterion $j$.

(3) Decision-makers compare all other criteria to the worst criterion on a 1–9 -point scale. This result portrays the Others-to-Worst (OW) vector as: $OW = \{a_{1W}, a_{2W}, \cdots a_{nW}\}$ where $a_{jW}$ is the preference of the criterion $j$ over the worst criterion $W$

(4) BO and OW vectors is put into a linear programming problem: min $\xi L$ subject to

$$w_B - a_{Bj} \times w_j \leq \xi L$$

$$w_j - a_{jW} \times w_W \leq \xi L \sum w_j = 1$$

$$w_j \geq 0, for\ all\ j$$

The linear programming problem is solved to get the optimal weights $(w^*, w^*, \cdots, w^*)$ and $\xi L^*$. 1 2 n.

The $\xi L^*$ depicts consistency. There is a higher consistency when the value of $\xi L^*$ is closer to zero. This means the comparison is more reliable.

*3.2 Case study*

Ghana's health sector increasingly relies on health data quality and preparation. Ghana's health records are mostly handled manually. There have been many problems with this manual method, including insufficient access to health records and poor communication between caregivers.

Ghana's health sector recognizes the need to incorporate technological innovations into the health sector. As a result, there have been many efforts to digitize the health sector in Ghana. For instance, the government inaugurated the national e-health strategy in July 2010 to streamline the regulatory framework for paperless record-keeping. Also, the Ghana Health Service has implemented the improved District Health Information Management System (DHIMS2) to help health facilities collect and analyze data. Notwithstanding the efforts, technology implementation in Ghana Health service has not yielded the needed results. For

instance, the Ministry of Health report revealed that no Logistics Management Information Systems (LMIS) provide comprehensive real-time information (Ministry of Health, 2018). Also, the systems do not provide enough security and confidentiality (Ministry of Health, 2018).

However, blockchain technology can ensure health information is available to healthcare providers while protecting patients' information from unauthorized people. Furthermore, blockchain-based health recording systems can monitor who accessed patient health data and even reject unauthorized attempts to manipulate health data.

This paper aims to provide health staff, policymakers and clinicians with an understanding of the main factors for implementing blockchain technology in the healthcare industry of emerging economies. A sample of 20 practitioners from the Ghana health industry with over eight years of work experience has been chosen to illuminate the applicability and usefulness of the proposed system and provide an extensive evaluation of blockchain technology. The experts were selected from many categories in the health supply chain. This is because blockchain trials and implementation in Ghana's public sector have become more intense since 2020 (Bai *et al.*, 2022). The multi-category respondents give a broader representation of the entire health supply chain. Each participant's perspective on blockchain application in the health supply chain differs. Also, the sample draws experts from different management positions. The selection criteria were based on experts having more than three years' of experience in the health industry. All these positions influence blockchain technology implementation in the health sector.

Table (2) presents summary characteristics of the experts (see Table 2).

### *3.3 BWM application*

*3.3.1 Determination of decision criteria.* Through the literature review, we identified 25 blockchain technology adoption criteria. We provided the initial step, a questionnaire with 25 blockchain adoption, to the experts for review at different times. We then asked experts to determine which criteria were more applicable to their organization's operations by choosing "1," for relevant and "0," for irrelevant.

We allowed the experts to suggest other criteria in the industry technology adoption. The experts agreed to include any criteria approved by at least 15 experts in the next round of the review. We refined the set of criteria after three rounds of interviews. We selected 17 blockchain technology adoption criteria (see Table 1).

*3.3.2 Selecting the best and worst criteria.* The 20 respondents indicated the best and worst criteria for adopting the blockchain using a survey. The best and worst results are illustrated in Table 3.

*3.3.3 Ranking the best criterion preference over others.* Decision-makers ranked the best criterion's preference over all others on a 1–9-point scale.

*3.3.4 Ranking the other criteria preference over the worst criterion.* Respondents ranked all other criteria over the worst on a 1–9-point scale. Table 4 shows a sample decision-maker ranking.

*3.3.5 Finding the optimal weights.* By solving the optimization model for each of the 20 respondents, we determined the optimum weights of each criterion. Then we calculated a simple weighted average of a single vector for each parameter. We illustrated a sample in Table 5. It shows that the consistency ratio ($\xi^{L^*}$) is close to zero; hence the comparisons are highly consistent and reliable. Figure 2 presents a bar graph of the sample main criteria weight. We also found the global weight by multiplying the weight of each main criterion by the corresponding local weights of each of their sub-criteria.

| Characteristics of experts<br>Characteristic | Number | Percentage (%) |
|---|---|---|
| *Age* | | |
| Below 40 | 8 | 40 |
| 40–59 | 12 | 60 |
| *Gender* | | |
| Male | 13 | 65 |
| Female | 7 | 35 |
| *Education* | | |
| Bachelor's degree | 4 | 20 |
| Master's degree | 6 | 30 |
| PhD/MD | 10 | 50 |
| *Work experience* | | |
| Between 8 and 19 years | 9 | 45 |
| Over 20 years | 11 | 55 |
| *Type of organization* | | |
| Ghana health service | 5 | 25 |
| Private health service facilities | 4 | 20 |
| Health NGOs | 4 | 20 |
| Ministry of health | 3 | 15 |
| Health sector ICT service providers | 4 | 20 |
| *Position* | | |
| Supply chain manager | 4 | 20 |
| Information management officer | 6 | 30 |
| Medical superintendent | 3 | 15 |
| Administrative manager | 3 | 15 |
| Accountant | 1 | 5 |
| Software developer | 3 | 15 |

**Source(s):** Authors' own work

**Table 2.** Characteristics of respondents

## 4. Results and discussion

Table 6 presents a summary of the BWM results.

### *4.1 Ranking the main criteria for blockchain adoption*

The findings suggest that technical factors highly affect the acceptance of blockchain technology in Ghana. Organizational factors and environmental factors accompany these. Technological aspects are essential and should be incorporated by organizations to increase the implementation of blockchain technology within the health sector. In previous research, technical factors involving compatibility issues, safety and data protection were critical for implementing digital innovations (Orji *et al.*, 2020). More critically, technical issues for blockchain implementation in healthcare supply chains are prevalent in emerging and developed economies. For example, Attaran (2022) reviewed the pivotal roles blockchain technology plays in solving some of the most critical and challenging issues facing the healthcare industry and observed that inefficient interoperability and information security are challenges in the USA healthcare industry. Interoperability poses a difficulty in identifying patients and information blocking where healthcare providers impose an unreasonable constraint on exchanging patient data or electronic health information. Also, he

| Blockchain adoption criteria | Number of experts selected as best | Number of experts selected as worst |
|---|---|---|
| Technological factor (TEC) | 8 | 4 |
| Organizational facto r (ORG) | 6 | 6 |
| Environmental factor (ENV) | 6 | 10 |
| Compatibility (TEC1) | | 3 |
| Security and privacy (TEC2) | 9 | |
| Immutability (TEC3) | 1 | |
| Infrastructural facility (TEC4) | 5 | |
| Access to blockchain technology and tools (TEC5) | 5 | |
| Ease of use (TEC6) | 3 | 7 |
| Perceived benefits (TEC7) | 1 | 10 |
| Capability of human resources (ORG1) | 2 | 5 |
| Organizational culture (ORG2) | 1 | 11 |
| Top management support (ORG3) | 2 | 3 |
| Perceived costs of investment (ORG4) | 7 | 2 |
| Presence of training facilities (ORG5) | 8 | |
| Market uncertainty (ENV1) | 3 | 9 |
| External stakeholder (ENV2) | 2 | |
| Competitive pressure (ENV3) | 1 | 4 |
| Government policy and support (ENV4) | 6 | 1 |
| Industry involvement (ENV5) | 8 | 1 |

**Source(s):** Authors' own work

**Table 3.** Best and worst main and sub-criteria identified by experts 1–20

| BO. | Technological (TEC) | Organizational (ORG) | Environmental (ENV) |
|---|---|---|---|
| Best criterion: TEC | 1 | 2 | 9 |

| OW | Worst criterion: ENV |
|---|---|
| TEC | 8 |
| ORG | 6 |
| ENV | 1 |

**Source(s):** Authors' own work

**Table 4.** Best-to-others (BO) and others-to-worst (OW) pairwise comparison for main criteria for expert 1

| Weights | TEC | ORG | ENT |
|---|---|---|---|
| | 0.6 | 0.33 | 0.07 |
| Ksi | 0.07 | | |

**Source(s):** Authors' own work

**Table 5.** Weights for main criteria

suggested the urgent need for a robust public health system that can collect, store, score and protect population health data in the USA healthcare industry.

The second major enabler is the organizational factors, including causes and problems connected with internal issues. The technology for blockchain includes the maintenance of hardware and software. With more comprehensive implementation, the costs associated with more investments rise. The total cost is the technology cost and people and process

infrastructure that will help the company and system partners (Schmidt and Wagner, 2019). The environmental factors have the smallest impact on blockchain acceptance in the health sector.

Our results confirm the strong impact of technological factors on environmental and organizational factors published in the literature (Wong *et al.*, 2020). Still, all factors must be considered in management decisions to obtain digital innovation. Institutions should establish cross-functional teams with multiple management groups to oversee blockchain adoption.

### *4.2 Global rank of individual enablers*

The findings indicate the global ranking of each enabler that influences blockchain adoption in the health industry, as illustrated in Table 6. The top two ranked enablers belong to the main technological factor, while the third and fourth belong to organizational and environmental factors. This ranking shows that "security and privacy" highly enhance the adoption of blockchain technologies in the health supply chain. Blockchain security and privacy features are very critical to the health supply chain. Patients' health information is confidential and must be secured from leaking to unauthorized persons. Leaked and medical data breaches expose health institutions to legal suits and loss of integrity.

Many authors also identified that blockchain technology in healthcare would be a feasible solution for securing health information (Hajian *et al.*, 2023). Interestingly, Orji *et al.* (2020) found "privacy and security" less influential in blockchain technology adoption in the freight logistic sector. This may be explained that freight logistics information may not be as confidential and private as patients' medical information that needs to be highly secured.

Infrastructure facility is the next critical enabler that influences the adoption of blockchain in the health sector. The presence of infrastructural facilities like information communications technology tools enhances the use of blockchain technologies in the health sector. Contrary to the perception that emerging economies lack blockchain infrastructure facilities to support their adoption (Yadav *et al.*, 2023), many authors have found technology infrastructure facilities in emerging economies. In Ghana, the government is piloting a blockchain project with Bitland to record land title deeds to reduce land fraud (Quayson *et al.*, 2020).

Other highly influential organizational and environmental factors are training facilities, government policy and support. The presence of training facilities ranked third, while government policy and support ranked fourth. Training enhances users' blockchain skills and exposes them to new knowledge. There are public and private blockchain training opportunities in Ghana. For example, Blockchain Academy provides extensive hands-on training about cryptocurrency, Bitcoin and Ethereum development platforms.

Technology investment is central to the present government regarding government policy and support, information and communication. Consequently, they have embarked on

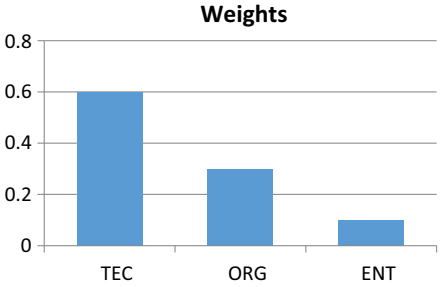


**Figure 2.**
Bar graph of sample main criteria weight

| Main criteria | Weight of main criteria | Rank of main criteria | Sub-criteria | Local weight | Sub-criteria rank | Global weights | Rank |
|---|---|---|---|---|---|---|---|
| Technological factor (TEC) | 0.372 | 1 | Compatibility (TEC1) | 0.076 | 6 | 0.028 | 16 |
| | | | Security and privacy (TEC2) | 0.242 | 1 | 0.090 | 1 |
| | | | Immutability (TEC3) | 0.126 | 4 | 0.047 | 13 |
| | | | Infrastructural facility (TEC4) | 0.231 | 2 | 0.086 | 2 |
| | | | Access to blockchain technology and tool (TEC5) | 0.181 | 3 | 0.067 | 7 |
| | | | Ease of use (TEC6) | 0.059 | 7 | 0.022 | 17 |
| | | | Perceived benefits (TEC7) | 0.085 | 5 | 0.031 | 15 |
| Organizational factor (ORG) | 0.322 | 2 | Capability of human resources (ORG1) | 0.155 | 4 | 0.050 | 10 |
| | | | Organizational culture (ORG2) | 0.147 | 5 | 0.050 | 12 |
| | | | Top management support (ORG3) | 0.177 | 3 | 0.057 | 8 |
| | | | Perceived costs of investment (ORG4) | 0.260 | 2 | 0.083 | 5 |
| | | | Presence of training facilities (ORG5) | 0.261 | 1 | 0.085 | 3 |
| Environmental factor (ENV) | 0.309 | 3 | Market Uncertainty (ENV1) | 0.135 | 5 | 0.415 | 14 |
| | | | External stakeholder (ENV2) | 0.168 | 3 | 0.517 | 9 |
| | | | Competitive pressure (ENV3) | 0.157 | 4 | 0.048 | 11 |
| | | | Government policy and support (ENV4) | 0.274 | 1 | 0.084 | 4 |
| | | | Industry involvement (ENV5) | 0.267 | 2 | 0.082 | 6 |

**Source(s):** Authors' own work

**Table 6.**
Weights, local weight, global weight and rank of main and sub-criteria

aggressive digitalization infrastructure development spanning many sectors of the economy. Even more significant government support of technology in Ghana's health sector is the ongoing introduction of medical drones and paperless public healthcare delivery. However, other studies have found some lackadaisical government attitudes supporting technological infrastructure development. This may be caused by the high investment cost and the perceived insecurity of blockchain technology (Villarreal *et al.*, 2023).

Compatibility and ease of use were ranked as the last two less influential factors. Other researchers have similar findings (Orji *et al.*, 2020). A possible reason is that Ghana's health service does not already use more sophisticated technology that may be incompatible with blockchain technology. Surprisingly, the ease of use ranked last. Blockchains are not easy to

use due to the lack of standardization of blockchain architectures. However, the exposure to similar technologies and high penetration of technologies in Ghana may make blockchain technology easier than envisaged.

*4.3 Rank of subcriteria in each main criterion*

Figure 3 provides the summary results of the rankings of sub-criteria in each main criterion.

*4.3.1 Technological main criteria.* Evaluating the enablers of blockchain technology adoption suggests that blockchain "security and privacy" has the highest rank. Improved security with blockchain prevents patients' information tampering, fraud and cybercrime. The next main sub-criteria is the infrastructural facility. It means adequate facilities are available to meet infrastructural requirements. Health institutions must provide adequate facilities such as radio-frequency identification systems (RFID), surveillance models and compatible IT platforms to enhance blockchain adoption. The third sub-criteria within the main technological criteria is access to blockchain technology. The adoption of digital innovations requires specific tools to ensure its success.

The next influential sub-criteria within the main technological criteria is immutability. The health information stored within a blockchain becomes immutable because the information joins the linear chain (Wang *et al.*, 2019). Another sub-criterion is the perceived benefits of adopting blockchain technologies in health care. An in-depth understanding of the benefits of blockchain technology can encourage health institutions to use it (Kamble *et al.*, 2019). Developers need to promote the potential benefits of blockchain technology and its use based on the organization's resources and characteristics (Hasselgren *et al.*, 2020). Compatibility and ease of use are the two least influential within the technology context. Interestingly, it is also the least significant on the global rank. We have given some possible reasons earlier.

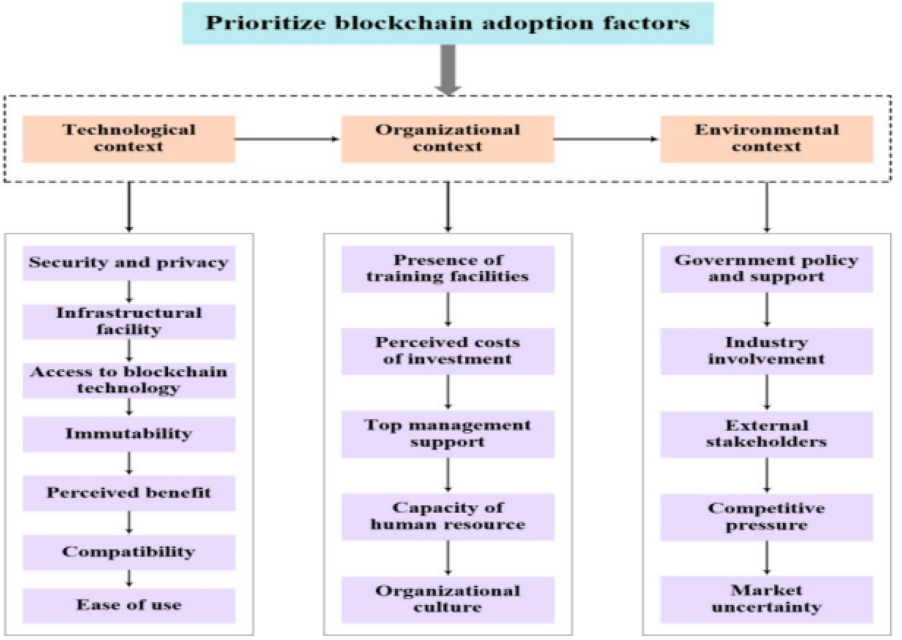


**Figure 3.**
BWM model to determine enablers for blockchain adoption

*4.3.2 Organizational factors.* The "presence of training facilities" rank highest among the organizational factors. The successful adoption of blockchain technology depends on the availability of suitable facilities for training employees of health institutions. Blockchains require specialized developers and many health institutions still have little knowledge. Also, few ready-to-use blockchain applications still exist (Rai, 2023).The perceived cost of investment is the next organizational factor. Information collection and conversion to new systems bring costs to health organizations. This perceived huge cost is also a barrier to health institutions with limited financial resources (Shahnaz *et al.*, 2019).

Top management support ranked third most important organizational factor. Top managers in health institutions ensure that they adopt blockchain technologies effectively. This is because top management influences organizational decision outcomes.

The last but one influential factor includes the capability of human resources. They may not be significant in the health sector because many workers who interact with technology have some necessary IT skills. Also, training facilities and government and management support may help employ and build the required capacity of employees to use the technology effectively. The least ranked factor is organizational culture. This finding reveals that experts in the health sector think that blockchain technology adoption's impact on their organizational culture is not too significant to them.

*4.3.3 Environmental factors.* The environmental factors had the lowest rank among the main criteria enablers. Among them, government policy and support had the highest rank. Prior literature has established the role of government policy and support in influencing the adoption of innovations (Mahajan *et al.*, 2023). Currently, government laws are still unclear about the use of blockchains. This affects the broader usage of blockchain technology.

Industry involvement ranked next. If all actors and leadership in the health industry involve themselves in the technology adoption process, sustaining the technology for its intended benefits will be easier. This is critical because the health supply chain consists of many actors. If an actor or group of actors do not involve themselves, it will hinder the industry from adopting the technology. The third-ranked environmental factor is the involvement of external stakeholders. Related NGOs, communities and regulatory bodies must support blockchain technology adoption in health institutions. Competitive pressure is the next important enabler. Competitive pressure in the health industry prevents each health institution from leaking its information through blockchains to avoid undermining its competitive advantage (Bai *et al.*, 2022). Market uncertainty ranked the lowest among the environmental factors. Uncertainty about market demands for blockchain technology relating to customers' behavior and productivity must be considered.

### *4.4 Managerial implications*

The results present policymakers and health sector managers with a hierarchical blockchain implementation guide. This is because of their incapability to incorporate all critical factors due to resource scarcity simultaneously (Quayson *et al.*, 2023a, b). For example, we suggest that health managers build strategies based on the importance of blockchain adoption enablers. Decision-makers should give blockchain's "safety and privacy concerns" critical attention. We encourage government agencies to enact policies and provide health institutions with a proper supportive climate to incorporate blockchain technology. We also encourage blockchain developers to provide health institutions with unique solutions for digital innovation decisions.

Regulatory authorities should provide financial incentives to minimize perceived high investments in blockchain technology. They should also enforce regulatory policies and improve legal structures to enable health institutions to embrace blockchains. In the USA, legislation was introduced to promote the blockchain (Tawiah *et al.*, 2022). For example,

regulatory support is improving, unlike in other countries where regulations prohibit the introduction of a smart contract.

Furthermore, healthcare administrators need to note the possible risks of using blockchain technology. For example, standardization of blockchain architectures remains missing, with more than 6,500 active GitHub blockchain projects in 2018, with projects focused on various privacy measures.

Blockchain implementation is in the early stages of adoption in the health sector. It requires a long-life implementation cycle, and its importance in business processes is unclear (Queiroz and Fosso Wamba, 2019). Advanced technological infrastructure is also necessary for the healthcare sector so that computers can connect to the Internet for processing transactions.

Moreover, regarding the similar nature of many African countries' health industries, the outcome of this study can be implemented in other African countries such as Togo and Nigeria. Furthermore, this study also provides significant implications for healthcare supply chains.

First, the findings suggest the importance of creating awareness by educating healthcare supply chain participants about using blockchain technology in healthcare information management (Esmaeilzadeh and Mirzaei, 2019). For instance, national educational programs, health conferences and webinars that are easily accessible to a wide range of healthcare supply chain participants can be administered to publicize blockchain-based healthcare information management's key goals and advantages. Educational forums available on official health websites, Web-based tutorials accessible on participants' portals or web-based health communities and computerized help programs can be used in the healthcare supply chain to improve the transparency of blockchain applications in information management, broadcast their expected benefits and increase public awareness and familiarity with this exchange mechanisms.

Second, regarding the importance of information privacy in blockchain-based healthcare information management, healthcare supply chain actors should consider using tactics to increase the transparency and completeness of privacy policy and invest considerable effort in developing campaigns that leverage the power of blockchain image and reputation in the healthcare supply chain.

Third, supply chain actors must revisit their supply chain strategy and address what they currently do regarding healthcare information management, why blockchain is required, what blockchain architecture is the best option and how they can implement it (Esmaeilzadeh, 2022). The unauthorized sharing of sensitive health information can erode public trust in healthcare systems. Healthcare supply chain participants can encourage increased adoption of blockchain for secure and interoperable information management. Blockchain system developers can also play an essential role in designing blockchain-based healthcare information management system that improves interoperability. Blockchain system developers must develop federated blockchain models for information management that enable healthcare supply chain participants to cooperate with various entities.

Finally, the adoption of blockchain technology may require healthcare supply chain participants to acquire new skills and knowledge. This may require training to ensure effective implementation.

## 5. Conclusion

Blockchain is one of the digital technologies of the next decade. Despite the many advantages this technology provides, the ties between the benefits and the lack of awareness are evident in the healthcare sector, where managers have little or no information about the efficiency of blockchain technology and its implementation (Kummer *et al.*, 2020).

This paper theoretically centered on the TOE framework to propose a decision framework for implementing blockchain technology in Ghana's health industry. We developed a BWM

modeling framework to rank the significant factors that affect the adoption of blockchains. We gathered data from 20 health industry experts in Ghana. The results showed that the main technological enablers are the most influential criteria for adopting blockchain than organizational and environmental enablers. Also, among the global ranking of the individual enablers, the top four include the availability of security and privacy, infrastructural facilities, presence of training facilities and government policy and support.

The findings offer an in-depth understanding of the critical factors that encourage blockchain adoption in the health sector, in contrast to previous studies focusing on blockchain implementation in broader supply chains. The study incorporates essential health considerations as a feature of blockchain adoption. This study provides a valuable framework for further and more detailed theoretical research on crucial factors for implementing blockchain technology, particularly in the health industry's emerging economies.

### *5.1 Limitations and future research directions*

While this research contributes to the literature, there are limitations like any other research. For example, only 25 enablers were identified from the literature and 17 were used finally. These constraints, however, present major pathways for further studies. For instance, another MCDM technique may be used to replace the BWM model. For example, the AHP, fuzzy set and decision-making trial and evaluation laboratory (DEMATEL) analyze the relative importance of essential factors affecting blockchains in the health industry.

Additionally, other sectors may be analyzed to understand the critical factors in the blockchain adoption process. Moreover, this study's findings can be generalized by considering different health facilities in Ghana and other emerging and developing countries like China and India. Other researchers can carry out a comparative study to inform about differences in the significance of variables in the various service contexts and countries. Finally, other studies can analyze the factors influencing blockchain technology performance. The relationship between "effective blockchain use" and "performance improvement in the health sector" continues to be limited by this study. Future studies can analyze this relationship.

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