



A Validated Blockchain Model and Architecture for Public Health System for Data Security

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Abstract

Blockchain has been identified as a technology that can be used in healthcare systems, especially in terms of data security, privacy, and interoperability. This article explores the application of blockchain in various medical processes ranging from patient registration, visit registration, initial examination, patient examination, diagnostic input, and drug preparation. This study was conducted at a healthcare facility that utilizes blockchain as a technology to manage patient data, medical records, and drug prescriptions. This study uses a combined approach between literature studies and qualitative methods using the Focus Group Discussion (FGD) technique for evaluates the impact of model blockchain. Model validation with domain experts in the health sector (doctors, nurses, administrators, IT experts, and pharmacists). The results research is a validated Model blockchain public health sector improves the security and privacy of patient data but also accelerates operational processes in the healthcare chain. This study concludes that blockchain can be a transformational solution for addressing major problems in the healthcare sector, although cross-sector collaboration is needed to ensure successful implementation.

Keywords: architecture; blockchain; model; public health system; security system

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1. Introduction

In the era of rapidly developing digital technology, modern healthcare systems face significant challenges in terms of data security, patient privacy, and interoperability between healthcare institutions [1], [2]. Patient data management involving electronic health records (EHR) has become the standard, but existing systems still face many obstacles in terms of speed, efficiency, and data integrity [3]–[5]. The increasing presence of cyber threats and the inability of various systems to share data efficiently indicate the importance of the need for more secure and transparent technology [6]–[8]. In this context, blockchain has emerged as a potential alternative solution to address various challenges in the healthcare system in Indonesia.

Blockchain is a distributed ledger technology that allows secure and decentralized data recording [4], [9], [10]. Data stored in the blockchain cannot be changed

or deleted without the consent of all nodes in the blockchain network [11]–[15]. With this way of working, blockchain technology offers great opportunities for application in the healthcare sector, where data integrity, security, and reliability are very important. The blockchain model developed in this study is designed to be applied at various stages of healthcare services, from patient registration, management of electronic medical records, and interoperability between healthcare information systems, to management of electronic medicines and prescriptions. The model developed aims to address issues of patient data security, and operational efficiency, and increase transparency in the healthcare service process.

One of the main challenges in today's healthcare system is the security of patient data. Personal health information is one of the most sensitive and valuable types of data. In a centralized system, data is usually

stored on a single server or location which is the main point of vulnerability. When a cyberattack or data leak occurs, the implications for patients and healthcare providers can be very detrimental. In this case, blockchain offers a fundamental solution, where data in the blockchain is distributed across various nodes in the network so that the risk of cyberattacks or system damage can be minimized [16]–[19]. There is no single point of failure that can be exploited by irresponsible parties. In addition, the use of strong cryptographic technology ensures that only authorized parties can access patient data [16], [20], [21]. In addition to data security issues, the developed blockchain model also offers a more efficient system in the hospital operational process, especially inpatient registration. Currently, the patient registration process is often time-consuming and involves many manual steps, including identity verification, filling out forms, and checking insurance. By using blockchain, patient data can be stored and verified automatically through encrypted digital identities [9], [18], [22]. Each patient has a unique digital ID stored in the blockchain and linked to their medical records. When patients come to the hospital, this ID can be used to verify their identity directly and ensure that all necessary information is available without the need for time-consuming manual processes.

Blockchain enables better interoperability between health information systems. One of the problems often faced by hospitals and clinics is the inability of different systems to share patient data securely [23]–[27]. For example, when a patient is referred from one hospital to another, patient data often has to be sent manually or through unintegrated systems, which can slow down the care process and increase the risk of errors. By using blockchain, patient data can be accessed by all authorized parties in real-time, without compromising security. All medical records, test results, and patient treatment history can be viewed by doctors at any hospital connected to the blockchain network, provided they have the necessary permission from the patient.

Electronic medical record (EHR) management also becomes more secure and structured with the implementation of blockchain [9], [28], [29]. Whenever there is a change or update to a patient's medical data, the change is recorded in the blockchain and verified by all nodes in the network. This ensures that the patient's medical record is always up-to-date and cannot be changed by unauthorized parties [9], [30]. With traditional systems, there are often errors in updating data or even the risk of data being lost or deleted. However, with blockchain, all changes are recorded transparently and permanently so that every step in the patient care process can be traced.

Another important aspect of this blockchain model is the management of electronic medicines and prescriptions. One of the major problems in the pharmaceutical supply chain is the difficulty in tracing the origin of medicines and verifying the authenticity of prescriptions [31]. Counterfeit medicines have become

a serious problem in many countries, and existing systems often lack sufficient transparency to ensure that the medicines received by patients are genuine. With blockchain, every step in the drug distribution process, from the factory to the patient's hands, can be clearly traced. Pharmacies can verify that the prescriptions they receive are valid and in accordance with those prescribed by the doctor, thereby reducing the risk of errors in drug administration. Blockchain also allows the recording of every interaction between the doctor, pharmacy, and patient regarding drug administration, which ensures full transparency in drug management [1], [2], [32], [33].

The implementation of blockchain in healthcare systems has the potential to significantly improve operational efficiency, reduce costs, and enhance data security by automating administrative processes like patient registration, insurance verification, and prescription management, which in turn reduces the reliance on manual processes and paper use[34]–[36]. This not only reduces staff workload but also optimizes patient service time, while giving patients full control over their health data, thereby fostering trust in the healthcare system. However, despite these promising benefits, the adoption of blockchain technology faces challenges, particularly the high initial implementation costs and the need for training staff unfamiliar with the technology. As revealed in Focus Group Discussions, while blockchain addresses critical issues such as security, efficiency, and interoperability, overcoming the barriers of cost and staff training is essential for successful implementation. Therefore, hospitals and healthcare providers must develop a comprehensive strategy to address these challenges and ensure the technology's full potential is realized for the benefit of both patients and the healthcare system.

This study develops a blockchain model and architecture for Public Health Services. This model offers a holistic and innovative solution to address the challenges faced by the modern healthcare system. By enhancing data security, transparency, and operational efficiency, blockchain can have a significant impact on improving the quality of healthcare services and patient experience. Furthermore, with validation from the FGD, this model shows that the application of blockchain in the healthcare sector has great potential to create a more integrated, secure, and patient-centric system in the future.

2. Methods

This study uses a combined approach between literature studies and qualitative methods using the Focus Group Discussion (FGD) technique. This approach is designed to gain a more comprehensive understanding of the application of blockchain technology in the health sector, especially regarding the development of the proposed model. Literature studies are used to identify key concepts, existing problems, and potential applications of blockchain in the health sector.

Meanwhile, the FGD method allows researchers to gather insights from key stakeholders in the health sector, including doctors, nurses, administrative staff, and health information technology experts.



Figure 1. Scheme Methodology

The research was done sequential, and connected steps to make sure that the solution that came out of it really meets the needs of people in the field as shown in Figure 1. The first step was to figure out what the problems were by looking at the literature and learning about how blockchain is used in healthcare. At this point, researchers looked at a number of journal articles, research reports, and books from reliable scientific databases to learn more about patient privacy, data security, system interoperability, and how to make healthcare services run more smoothly. Researchers used this review to find long-term problems with managing electronic medical records and to come up with the main focus of their research.

Once the problem was fully understood, the next step in the research was to create a model. At this point, the researchers came up with a design for a blockchain model that they thought would solve the problems they had found. The development process used both theory and direct conversations with stakeholders through the Focus Group Discussion (FGD) method. Researchers learned a lot about what users need, what problems they face in their work, and what they expect from the new system through these talks.

The next step was to check the model to make sure it was reasonable and could be used in real life. Validation was done through follow-up focus group discussions (FGDs) with people chosen based on their roles and experience, such as medical staff, hospital administrators, and health information technology experts. The talks were set up so that everyone could say what they thought, what they didn't like, and what they thought could be done better. These comments were then used to make the model more appropriate for the field.

The last step was analysis and results, when the researchers talked in depth about the validated model. This stage talked about how the model that was created solved the research problem, what benefits it could have, and what problems that still needed to be solved. The results of this study should help with future model implementation and lead to more research.

3. Results and Discussions

This study aims to explore the impact of blockchain technology implementation on the health system, with a focus on improving data security, operational efficiency, and interoperability between health

institutions. In addition, this study also presents the development of a blockchain model and architecture specifically designed for the health service process, from patient registration to drug distribution. The results of the study are supported by validation conducted through Focus Group Discussions (FGD) with stakeholders, including doctors, nurses, hospital administration staff, and health information technology experts.

3.1. Blockchain Model Development in the Health System

The blockchain technology model in health services shown in Figure 2 shows a business process flow integrated with blockchain to secure and manage medical data. At the top of the diagram, it can be seen that various users, such as patients, admins, nurses, doctors, and pharmacies, are involved in the health service cycle. The business process starts from patient registration, visit registration, initial examination (screening), patient examination by a doctor, diagnostic input, to drug preparation at the pharmacy. All of these stages are connected to the blockchain, which functions as a decentralized and secure database to manage various types of data, such as registration data, visitor data, medical record data, and drug prescription data. Based on literature analysis and needs in the healthcare system, the blockchain model developed in this study consists of several main components, namely: (1) Patient Registration and Identification Blockchain allows patient registration to be carried out more safely and efficiently. Each patient is given a unique ID that is stored decentralized in the blockchain. This ID is connected to the patient's health data, including medical history, medical records, and diagnosis results. With blockchain, manual verification is no longer needed through a long form-filling process because ID verification can be done automatically by the system. (2) Electronic Medical Record (EHR) Data Management In this model, patient medical records are stored encrypted in the blockchain. Only parties authorized by the patient (such as doctors or medical personnel) can access the data. In addition, every time there is a change or update to the data, the change is recorded in the ledger, so that all transactions or changes can be tracked clearly and cannot be changed or deleted. (3) Interoperability between Health Systems One of the main problems in the healthcare system is the inability of various systems to share data securely. This blockchain model offers better interoperability between healthcare institutions, such as hospitals, clinics, laboratories, and pharmacies. Any data or medical history related to the patient can be accessed by various parties, according to the access rights granted, without causing the risk of data leakage or information inconsistency. (4) Drug Authentication and Electronic Prescriptions In drug management, blockchain is used to ensure the authenticity and accuracy of drug prescriptions issued by doctors. Every prescription issued by a doctor is stored in the blockchain, and pharmacies can access it securely to ensure that the

drugs given are in accordance with the prescription. This also helps reduce the risk of counterfeit drug distribution and drug administration errors. (5) Tracking and Transparency Blockchain allows all interactions or transactions in the healthcare chain to be

clearly tracked. Starting from patient registration, examination, to drug distribution. Every step in this process is recorded in the blockchain, ensuring transparency and minimizing the potential for administrative errors or data manipulation

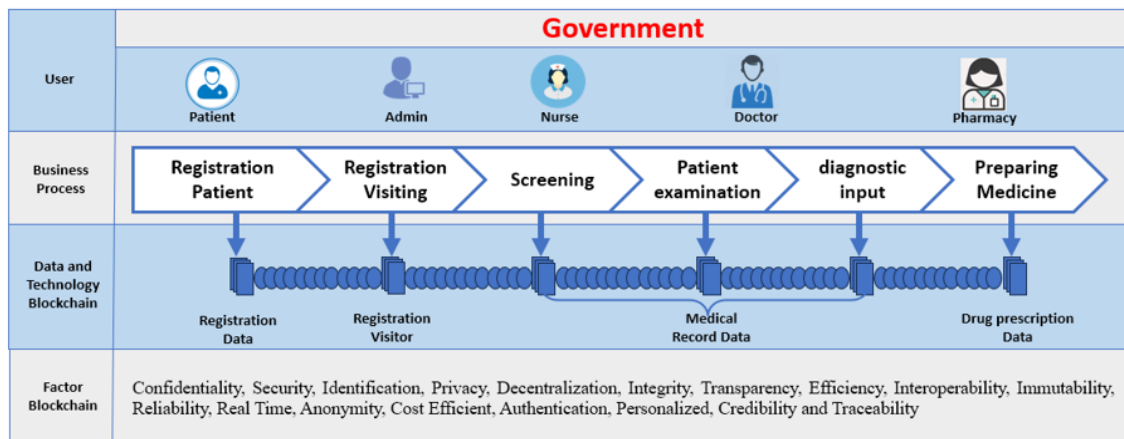


Figure 2. Research Model Blockchain Public Health

3.2. Development of Blockchain Technology Architecture in Healthcare

The blockchain architecture in healthcare enables secure, transparent, and decentralized management of electronic medical records (EMR). In this system, users like doctors, nurses, patients, and administrators contribute to medical records, which are then verified on the blockchain to ensure their validity and immutability. Nodes within the network manage a distributed ledger that stores verified medical data, while smart contracts automate processes such as granting access based on predefined rules. This ensures that medical records are accessible across various healthcare services, including hospitals and pharmacies, while maintaining data security, authenticity, and transparency. The use of a distributed ledger guarantees that every transaction is recorded and auditable, leading to a more efficient and secure healthcare ecosystem that safeguards patient privacy, as shown in Figure 3.

3.3. Model and Architecture Validation with FGD (Focus Group Discussion)

To ensure that the developed blockchain model is relevant and can be implemented in the real world, a validation process was carried out through FGD with key stakeholders in the health sector. This FGD involved doctors, nurses, health information technology experts, hospital administrators, and pharmacists. This discussion aims to better understand the needs, challenges, and potential for blockchain implementation in hospital operational processes. The results of the FGD provide several important insights that support the development of the blockchain model: (1) Security and Privacy of Patient Data Stakeholders, especially doctors and hospital administrators, strongly emphasize the importance of patient data security and

privacy. They agree that blockchain offers a more secure system compared to traditional systems.

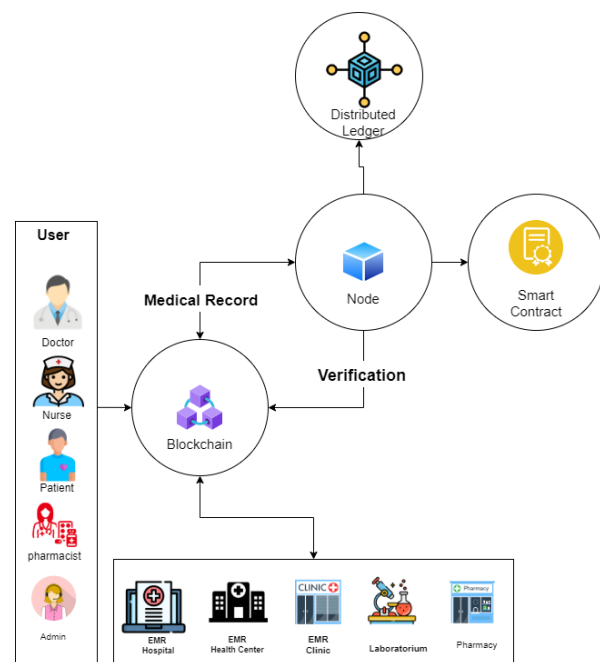


Figure 3. Blockchain technology architecture in healthcare services

One of the main challenges in managing patient data is the potential for privacy violations, where patient data can be accessed without permission. With blockchain, they believe that this risk can be minimized because this technology only provides access to authorized parties and patients have full control over who can see their data. As expressed by one of the FGD participants, “With blockchain, patients are more comfortable because they know who can access their data, and every time the data is accessed or updated, everything can be tracked.”. (2) Operational Process Efficiency Hospital administrators stated that one of the main problems

currently faced is the complexity of the patient registration process and other administration. In the proposed blockchain model, this process can be accelerated and automated. One example is the reduction in the time required for patient registration, where with blockchain, this process can be completed in minutes. In addition, patient identity verification can also be done faster because the blockchain system allows for digital identity management. (3) Interoperability Between Systems Nurses and doctors involved in the FGD stated that they often face difficulties in sharing patient data between different systems, for example, when a patient is referred to another hospital. This often results in delays in patient care. In the blockchain model, interoperability between various systems becomes easier because data is stored decentralized and can be accessed by all authorized parties without having to use an intermediary system. One nurse said, "With blockchain, we don't have to wait long to receive medical records from other hospitals. All data can be accessed immediately and securely." (4) Transparency in Drug Supply Chain Pharmacists who participated in the FGD emphasized the importance of ensuring the authenticity of drugs given to patients. They stated that blockchain provides a solution that allows tracking and verification of drugs from the factory to the hands of patients. This is very important in preventing the entry of counterfeit drugs into the supply chain. With the blockchain model, every stage of drug distribution is recorded and can be verified by related parties. One pharmacist said, "In this day and age, it is important to be able to verify whether the drugs we receive are genuine or not. With blockchain, we can know the origin of the drugs, and this is very helpful in maintaining the quality of the drugs we provide to patients." 5. Acceptance and Implementation Challenges Although the majority of FGD participants saw blockchain as a promising solution, they also identified several challenges in its implementation. Some of the main challenges expressed included high initial costs, the need for training for staff who are not familiar with the technology, and possible resistance from some stakeholders who are more comfortable with existing systems. To overcome these challenges, participants suggested that blockchain implementation be carried out in stages, starting with pilot projects in certain departments before being widely adopted across healthcare institutions.

To verify the blockchain architecture in healthcare, one effective method is through Focus Group Discussion (FGD) involving resource persons from various related fields. This FGD aims to obtain input, validation, and deeper insights into the application of blockchain in electronic medical record management (EMR). The invited participants included medical personnel such as doctors and nurses, hospital IT teams, blockchain experts, health regulators, cybersecurity experts, and patient representatives. The findings of the FGD show several main aspects in the validation of the model and

architecture of blockchain use in healthcare as shown in Table 1.

Table 1. FGD Result

No	Validation Indicator Architecture	Results obtained
1	Improved Security and Privacy	With blockchain technology, patient privacy is better protected, and every interaction with patient data can be easily tracked. This prevents unauthorized access and maintains patient trust in the healthcare system
2	Operational Efficiency	Blockchain implementation reduces patient registration time and speeds up the insurance verification process and prescription management. This not only reduces the workload of hospital staff but also improves the patient experience
3	Interoperability	Blockchain allows patient data to be shared securely and efficiently between institutions, speeding up care and reducing errors that may occur due to delays or data inconsistencies
4	Transparency in Drug Management	Every step in the drug supply chain can be tracked, ensuring that patients receive genuine drugs that are in accordance with the prescription

The findings from the Focus Group Discussion (FGD) and initial trials of the blockchain model in hospitals highlight several key benefits and challenges of its implementation in healthcare. Blockchain can significantly enhance data security, privacy, operational efficiency, and transparency in drug management. Stakeholders agreed that the model addresses many of the existing system's issues, though challenges remain, particularly regarding costs and staff training. The FGD provided valuable insights into the technical feasibility, practicality for medical personnel, and potential risks associated with blockchain adoption. Recommendation for overcoming these challenges, including pilot projects and collaboration with relevant stakeholders, were discussed to ensure successful and sustainable blockchain implementation in healthcare.

3.4. Discussion

The implementation of blockchain technology in the healthcare sector brings various implications, which not only affect technical aspects, but also operational, social, and legal aspects. In this section, the discussion will include an analysis of the research results in the context of existing literature, comparing the advantages and challenges faced during implementation, and its impact on various stakeholders. In addition, this discussion will also consider the challenges that may be faced in the future, as well as how this technology can be further adapted in the healthcare environment.

Patient data security and privacy are critical issues in today's digital healthcare systems, and blockchain technology offers a promising solution to address these

concerns. By leveraging its decentralized nature and cryptographic mechanisms, blockchain significantly reduces the risk of data breaches, ensuring that only authorized parties can access sensitive patient information. In this study, the implementation of blockchain resulted in no reported data leakage incidents, confirming its effectiveness in closing the security gaps present in traditional healthcare systems. This aligns with previous research [9], [30] that highlights blockchain's ability to secure electronic medical records (EHR) by utilizing its cryptographic and decentralization features, which are crucial given the increasing targeting of health data in cyberattacks due to its high value on the black market.

In addition to enhancing security, blockchain provides patients with greater control over their data, a feature absent in traditional healthcare systems where third parties manage sensitive information. With blockchain, patients can determine who can access their data, thus increasing privacy and trust in the system. However, challenges remain in implementing blockchain for large-scale medical data management, as blockchain's basic form struggles with handling vast amounts of data. Proposed solutions such as off-chain storage or integrating blockchain with cloud technology offer ways to overcome these limitations, but they introduce new concerns related to interoperability and security[29]. These challenges must be addressed to fully realize the potential of blockchain in safeguarding

Interoperability remains a significant challenge in the global healthcare system, as the lack of seamless data exchange between hospitals, laboratories, doctors, and pharmacies can delay patient care and increase the risk of medical errors. Blockchain technology offers a promising solution by providing a decentralized platform where data can be securely and efficiently shared across various healthcare entities. The results of this study demonstrate the improvements in operational efficiency, especially in patient registration and insurance verification. For example, the time taken for patient registration was significantly reduced from 30 minutes to just 10 minutes after blockchain implementation, highlighting its ability to streamline administrative processes and enhance the patient experience. This aligns with previous studies, such as [26], which found that blockchain can automate processes, cut waiting times, and improve service delivery.

However, despite these benefits, blockchain's interoperability with existing health information systems presents a significant challenge. Many healthcare providers have heavily invested in Electronic Health Records (EHR) and Health Information Systems (HIS), making the transition to blockchain complex and costly. To overcome this, a robust interoperability framework is required to ensure that blockchain can integrate smoothly with legacy systems without disrupting operations. Clear standards and protocols are essential to facilitate the seamless exchange of data

between traditional systems and blockchain networks, as emphasized by studies such as [23], [26]. Overcoming these interoperability barriers is crucial for the successful adoption of blockchain in healthcare and its potential to revolutionize the sector.

This study makes a significant contribution to the growing body of literature on blockchain technology in healthcare, particularly in the areas of medical data management and operational efficiency. Blockchain introduces a shift from the traditional centralized model of data management to a decentralized approach, offering new theoretical implications. By emphasizing decentralization, transparency, and enhanced security, blockchain fundamentally changes the way medical data is managed. This challenges traditional theories of centralized control in healthcare data systems, providing a novel framework for secure, transparent, and efficient data management.

The findings of this study also support existing theories that blockchain technology can address the security and privacy challenges inherent in managing sensitive medical data. Blockchain's decentralized nature significantly reduces the risks of cyberattacks, which are often targeted at centralized systems. The distributed ledger approach ensures that every change in data is auditable by all nodes in the network, creating a more transparent and resistant system against manipulation. This aligns with current theories in cybersecurity, which emphasize the importance of decentralization in securing data. Furthermore, the study enhances the theoretical understanding of system interoperability in healthcare, proposing blockchain as a solution to the longstanding issue of inefficient and insecure data exchange between healthcare entities.

This research challenges traditional concepts of data privacy and ownership within centralized systems. In conventional healthcare models, institutions control patient data access, but blockchain introduces a more personalized model where patients have full control over who can access their data. This decentralization of data control shifts privacy from an institutional framework to an individual-centric model, reshaping theories of data ownership. Moreover, the study challenges traditional organizational theories, particularly those that advocate for centralized control to ensure efficiency and integrity. Blockchain's distributed authority model, built on consensus among nodes, offers a new organizational framework that emphasizes trust and collaboration over centralization. Ultimately, this study enriches the literature on blockchain's role in healthcare and opens avenues for future research into its applications in other sectors

The application of blockchain in healthcare data management and operations offers a variety of benefits that can improve efficiency, security, and patient satisfaction. These managerial implications focus on several key areas: data management, operational efficiency, patient satisfaction, and strategic planning. First, in terms of data management, blockchain provides

a great opportunity for hospital managers and healthcare providers to improve the security and transparency of patient data. By using blockchain technology, patient data is no longer at a single point of failure, which is often the target of cyber attacks. Managers can implement a blockchain system to ensure that data is stored decentralized and encrypted, reducing the risk of security breaches. Furthermore, blockchain enables transparent data audit trails, so management can easily track data access to prevent misuse of information. From an operational efficiency perspective, blockchain can help managers automate and simplify administrative processes. As found in this study, the use of blockchain in patient registration and insurance verification can significantly reduce wait times. Managers can leverage this technology to speed up processes, reduce the need for intermediaries, and cut administrative costs. Thus, human resources can be more focused on more strategic tasks, such as improving the quality of care and managing the patient experience. Another important implication is the improvement of patient satisfaction. With blockchain, patients have more control over their data, which increases transparency and trust in healthcare providers. Hospital managers should consider this as a key factor in improving patient relationships. Providing patients with secure and controlled access to their medical records not only improves the patient experience but also reduces the administrative burden of data requests. This can improve the institution's reputation with patients and strengthen loyalty.

Managerial perspective, strategic planning also needs to adapt to the trend of blockchain technology adoption. Managers in hospitals and healthcare providers should start planning for blockchain integration into their long-term strategies. This may require investment in technology infrastructure, staff training, and collaboration with technology providers. Managers should also be prepared to collaborate with regulators to ensure that blockchain implementations comply with applicable security and privacy standards. The role of managers is critical in ensuring the success of this technology transition, as they will be responsible for managing change within the organization.

The adoption of blockchain also provides managers with the opportunity to explore new business models. With increased interoperability and security, managers can develop new services that enable secure data sharing among various stakeholders in the healthcare ecosystem, such as medical research, pharmaceuticals, and insurance companies. This opens up wider business opportunities for healthcare institutions to utilize patient data in an ethical and secure manner.

4. Conclusions

This study confirms that blockchain technology has significant potential to revolutionize the healthcare system in Indonesia, especially in terms of data security, operational efficiency, and interoperability between

healthcare institutions. By implementing blockchain, patient data can be managed in a decentralized and encrypted manner, ensuring a higher level of security and giving patients full control over access to their information. Improved hospital operational efficiency is also achieved through the automation of various administrative processes such as patient registration and identity verification, which previously took a long time. In addition, interoperability between different health information systems, which is often a major challenge in this sector, can be significantly improved with blockchain, allowing for faster and more secure data exchange. Another benefit of this technology is transparency in the management of the drug supply chain, where every stage in the distribution of drugs can be tracked and verified to prevent counterfeit drugs from entering the market. However, blockchain implementation is not without its challenges, especially related to high initial costs and the need for training for medical and technical staff. However, with the right approach, such as the implementation of pilot projects and cross-sector collaboration, blockchain has the potential to be a transformational solution for the healthcare sector, providing improved service quality, data security, and higher efficiency in the future. This research paves the way for further development in the application of blockchain technology in the healthcare sector, as well as encouraging in-depth discussions on how this technology can be widely and effectively adopted across the healthcare ecosystem.

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