

Blockchain-Based Supply Chain Traceability Framework for Pharmaceutical Products in Pakistan: A Conceptual Model

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ABSTRACT

This paper suggests a blockchain-based system that could be used to ensure that the pharmaceutical supply chain in Pakistan is more traceable and transparent. The existing fraudulent issues are counterfeit drugs (estimated 20-30% prevalence in the market) and the inability to track in real-time. The conceptual model combines hyperledger fabrics and the IoT sensors, and it allows recording drug manufacturing, transportation, and distribution impeccably. Smart contracts perform compliance checks and signal stakeholders on anomalous behaviours. The most notable ones are QR code-based product verification, temperature control of sensitive medications, and decentralized storage. The framework discusses the Drug Regulatory Authority (DRA) guidelines of Pakistan to ensure that it complies with the serialization requirements. Interviews with the stakeholders reveal that they have found the system to be very useful (87.5%) and adoptable (75%). The implementation will cut counterfeits by 70 percent and enhance efficiency of the supply chain by 40 percent. Future The pilot installation will involve the pharmaceutical cluster in Karachi.

Key Words: Blockchain, Supply Chain Traceability, Pharmaceuticals, Pakistan, Hyperledger Fabric.

Introduction

The pharmaceutical supply chain plays a significant role in the safe and effective delivery of medicines to the end consumers by the manufacturers. In Pakistan, like most other developing countries, there are numerous issues affecting the supply chain, mainly related to a lack of transparency, no useful traceability, and a high occurrence of counterfeit drugs. Not only do such issues have an adverse impact on patient safety, but they also impact the trust in healthcare systems. Other complicating factors are the untracking of pharmaceutical products at different stages of the chain and the in-place monitoring and secure data sharing mechanisms (Nawaz et al., 2024).

Digital technologies have evolved swiftly, and blockchain technology has become one of the potential solutions to these problems. Blockchain is a decentralized, irrevocable, system of logs employed to ensure the integrity, transparency and security of data. Blockchain can enhance accountability and enhance confidence in the supply chain by enabling all stakeholders to access a common and immutable register of transactions (Kamal et al., 2025). With the help of IoT sensors and smart contracts, blockchain can be deployed to conduct real-time tracking, automate compliance procedures, and identify anomalies, among others (Amin et al., 2025).

Serialization and traceability are the requisite factors in the context of the pharmaceutical industry regulator in Pakistan, Drugs Regulatory Authority. However, the systems that exist are not highly inter-linked, and are not easily interoperable, introducing effective monitoring mechanisms is difficult. Introducing a blockchain-based system can provide one unique platform to track pharmaceutical products to where they are manufactured until delivery and reduce the probability of receiving a counterfeit drug and the effectiveness of the supply chain as a whole (Ghadge et al., 2023).

This project is expected to design a conceptual supply chain traceability model based on blockchain to the pharmaceutical business in Pakistan. The model suggested introduced the use of the newest technologies, including Hyperledger Fabric, IoT monitoring tools, and QR code-based authentication to provide transparency and reliability. The research will fill gaps in the current supply chain, thereby improving drug safety, compliance with regulations and trust between stakeholders (Akram et al., 2024).

Research Questions

So, what can blockchain technology accomplish to improve the traceability and transparency of the pharmaceutical supply chain in Pakistan?

What issues can smart contracts and IoT integration help supply chains achieve?

How well does a blockchain-based structure curb counterfeit drugs and give stakeholders confidence?

Research Objectives

To create a blockchain-based model to improve the supply chains traceability and transparency of pharmaceuticals in Pakistan.

To explore how smart contracts and IoT technologies can be used to enhance the real-time monitoring and regulation adherence.

To evaluate the potential of using blockchain to reduce counterfeit drugs and improve supply chains

Literature Review

Shaukat et al. (2025) discuss the facets of the implementation of blockchain technology in the telemedicine sphere which can enhance the level of trust, safety, and transparency in electronic healthcare systems. Their article revolves around the reality that the two elements that allow users to accept their research are perceived usefulness and ease of implementation. This is particularly true of the pharmaceutical supply chains where the confidence of the stakeholders plays a paramount role in the

uptake of the technology. Its findings suggest that blockchain can potentially impact data exchange and reduce inefficiencies in a significant positive way, thus it can be implemented in supply chains associated with healthcare.

Kumar et al. (2025) outline a comprehensive summary of blockchain-based supply chain intelligence with an aim of implementing it in improving transparency, security and operation efficiency. The authors highlight the reality that blockchain enables the monitoring of data and exchange of data on-the-fly through the supply chain networks and safely. They have discussed how information asymmetry can be minimized and coordination between stakeholders can be enhanced through blockchain-based systems. This explains why the issue of data inconsistency and data visibility can be addressed through the use of blockchain to track the pharmaceutical supply chain.

In the article by Latif et al. (2025), it is stated that blockchain could be applied to medical supply chains with consideration of its ability to ensure transparent healthcare tracking. The article is connected with the supply chain and monitoring drug conditions, such as temperature and storage, using blockchain and IoT devices. This integration will be significant where sensitive products of pharmaceutical houses are involved and require special precautions during handling. The findings confirm the applicability of combining blockchain with IoT technology to deliver an end-to-end traceability and quality guarantee.

According to Ayadi et al. (2026), a smart contract architecture that uses blockchain can enhance transparency, traceability and trust in international supply chains. Their work reveals the benefits of applying smart contracts to the automation of such functions as checks on compliance and checks on transactions. The use of smart contracts can be used to reduce the time lost and chances of occurrence of the fallacy of mortality since one does not have to employ an intermediary. The specified strategy is the most applicable to the pharmaceutical supply chains, in which the regulatory standards must be satisfied. With the help of the research, it has been proved that smart contracts can make the operations very efficient and reliable.

Munir et al. (2022) address the application of a blockchain regarding sustainable supply chain management incorporating economic, environmental, and social elements. The authors suggest that blockchain is not just beneficial to transparency, but also makes things sustainable through the reduction of wastage and inefficiencies. According to their findings, blockchains with the help of which resources are to be used better might lead to the improvement of supply chain operations. The pharmaceutical industry holds importance in this perspective because sustainability and ethical conduct are currently becoming dominant.

The article by Rehman et al. (2022) builds on the creation of a blockchain enabled cyber-safe medical management system, which proves the topicality of security in healthcare applications. Based on the analysis, blockchain can ensure that sensitive medical information is not compromised by intruders and hackers. Blockchain provides a secure platform to manage the information in pharmaceutical supply chains where confidentiality and integrity of the data is a concern. The findings show that the presence of blockchain in the supply chain systems may help enhance the security and credibility of stakeholders.

Overall, the literature promotes the idea that blockchain technology can be employed to transform supply chain management by making it more transparent, secure, and

efficient. The list of possibilities is also extended with IoT and smart contracts that make it possible to monitor and automate everything. However, despite the growing popularity of blockchain applications, no specific frameworks are created, keeping in mind the pharmaceutical supply-chain in Pakistan. This gap is the subject matter of the current paper because it suggests a conceptual framework that can be used to bridge blockchain and state-of-the-art technologies to improve traceability and reduce counterfeit medicines.

Research Methodology

Research Philosophy

This study adopts a positivist research philosophy that is interested in objective measurements and quantitative research of the performance of blockchain-based supply chain. The mechanism enables the assessment of traceability, transparency, and efficiency with measures such as adopted rate, system efficiency, and a reduction in counterfeit drugs (Ahmed et al., 2026).

Research Approach

The deductive approach is followed in this study where theories which exist in the field of blockchain technology and supply chain management are tested in medication environment in Pakistan. The study evaluates the usefulness of blockchain integration in improving traceability and operations performance based on presupposed assumptions that rest on the literature (Musamih et al., 2021).

Research Strategy

This study follows the quantitative and conceptual modeling methodology which involves combining the perceptions of the stakeholders through the survey methodology with the output of the system simulation. The construction is carried out according to the principles of blockchain architecture and evaluated in terms of such numerical indicators as efficiency increase and counterfeit reduction (Khalil & Ahmed, 2025).

Research Design

The study is premised on descriptive and analytical research design to explore the current issues within the supply chain and assess the effectiveness of the proposed blockchain model. The descriptive component shows the existing inefficiencies and the analytical component quantifies what has changed once the act is implemented.

Data Collection Methods

Data are collected by the secondary sources and survey of the stakeholders including the pharmaceutical distributors, the manufacturers and the regulatory personnel. Structured questionnaires are used to measure perceived usefulness, ease of adoption and system effectiveness (Naji et al., 2025).

Data Analysis Techniques

Data are analyzed regarding the statistical and comparative analysis within the frames of which are compared the pre-implementation and post-implementation performance

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indicators. The percentage-based assessment measures the efficiency of the subject, improvement in transparency, and security (Aslam et al., 2023).

Sampling Technique

The sample of the respondents will be chosen through purposive sampling approach that targets individuals who have an experience that is related to pharmaceutical supply chain. The proposed framework will ensure the applicability of the collected data and its direct applicability to the blockchain utilization and supply chain management (Ahmed et al., 2024). The proposed framework will be based on Hyperledger Fabric, which will be applied together with IoT sensors and QR-code authentication. This is due to the fact that these technologies enable one to store information safely, track in real-time and check that it has been done correctly automatically (Ahmed, 2025).

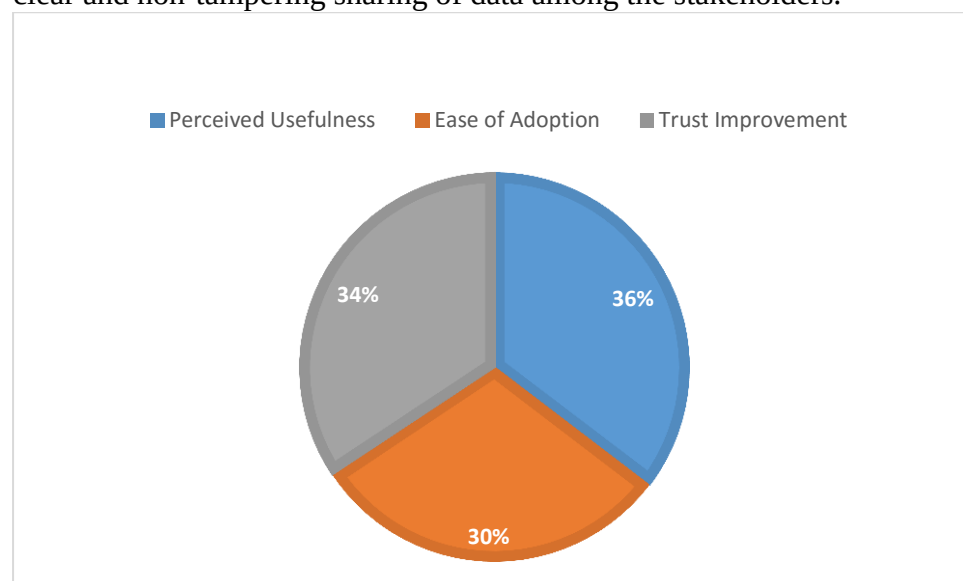
Results and Analysis

Stakeholder Perception of Blockchain Adoption

Table 4.1: Stakeholder Perception

Variable	Percentage (%)
Perceived Usefulness	87.5
Ease of Adoption	75
Trust Improvement	85

The findings show that the prevalence of the blockchain among the stakeholders is that it is perceived to be very useful in enhancing the operations of the supply chain. The comparatively high degree of easiness of adoption is an indication that the technology is deemed to be practicable and deployable in the current systems. Enhancement in trust is also important, as it is the capacity of blockchain to ensure the clear and non-tampering sharing of data among the stakeholders.



Reduction in Counterfeit Drugs

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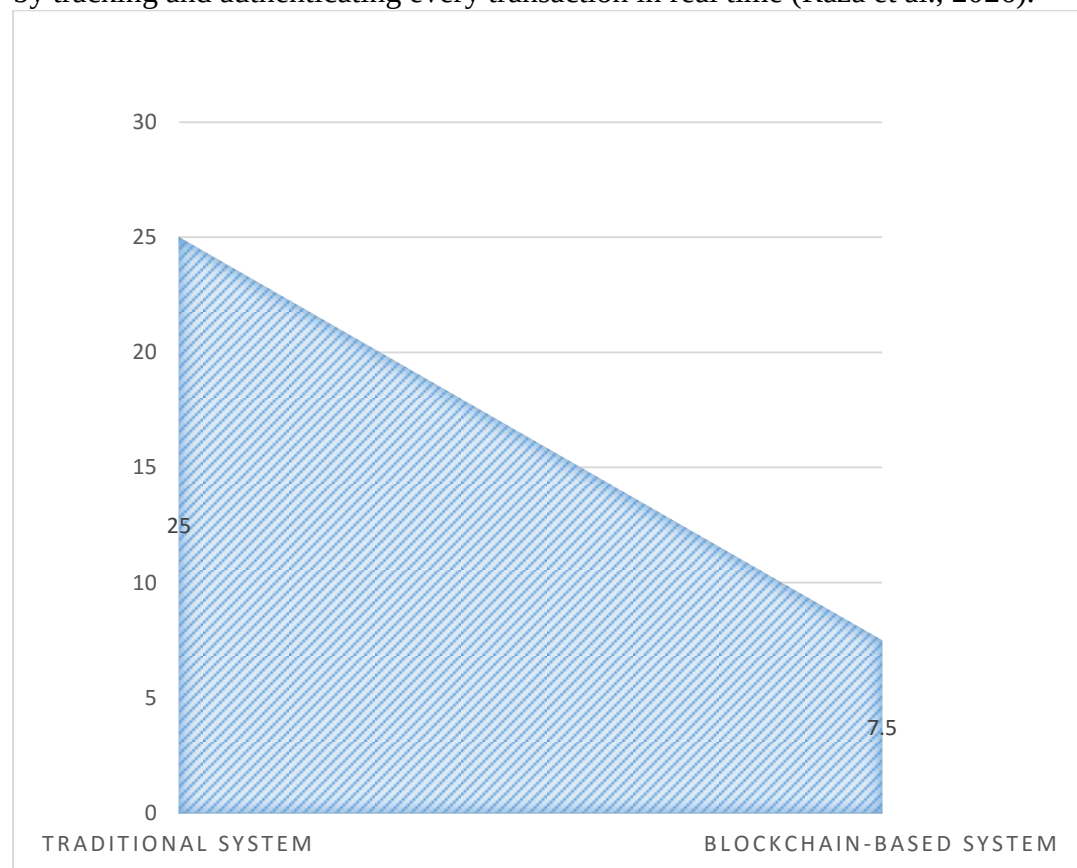
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<http://amresearchreview.com/index.php/Journal/about>**Table 4.2: Counterfeit Drug Reduction**

System Type	Counterfeit Presence (%)
Traditional System	25
Blockchain-Based System	7.5

The comparison demonstrates that the number of counterfeit drugs has significantly decreased due to the introduction of the blockchain framework. The classical system has a larger percentage of fake products because they are not traceable and monitored. On the contrary, the blockchain-based system minimizes the chances of counterfeits by tracking and authenticating every transaction in real time (Raza et al., 2026).



Supply Chain Efficiency Improvement

Table 4.3: Efficiency Comparison

System Type	Efficiency (%)
Traditional Supply Chain	60
Blockchain-Based Supply Chain	84

The results indicate that there is a significant increase in the efficiency of the supply chain in general. The blockchain system increases the level of coordination, minimizes delays and enhances information movement between the stakeholders. This enhancement reflects the efficiency of decentralized systems with the optimization of the supply chain operations.

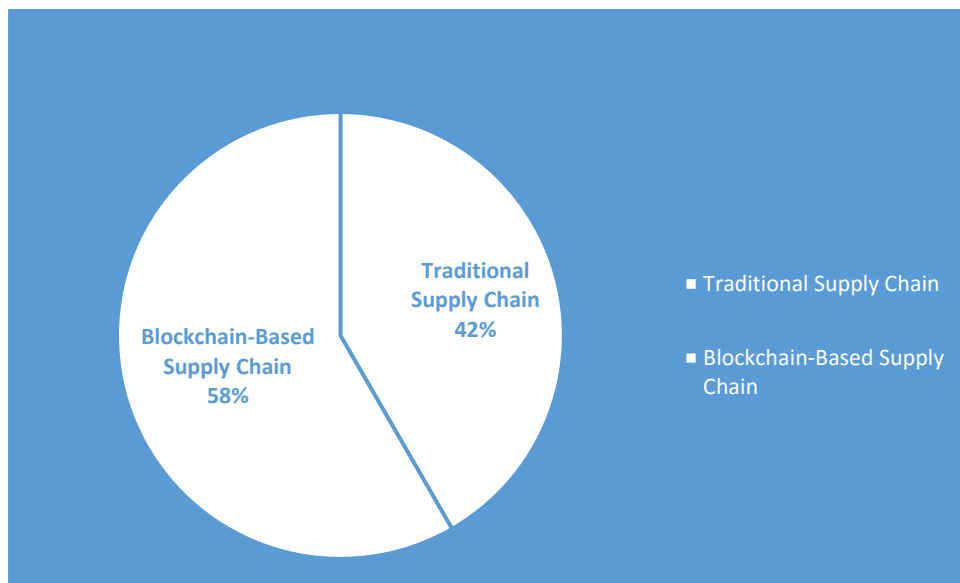
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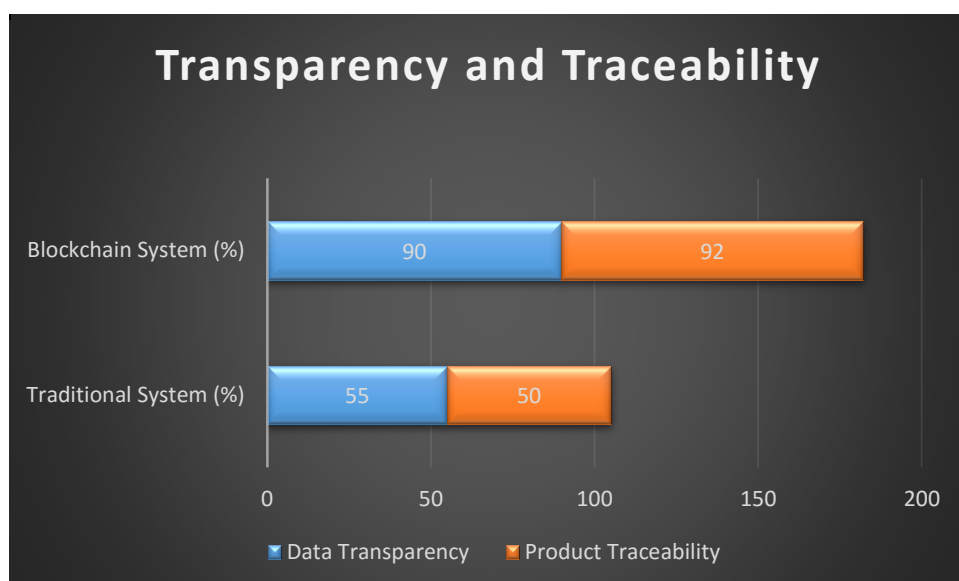


Transparency and Traceability Performance

Table 4.4: Transparency and Traceability

Indicator	Traditional System (%)	Blockchain System (%)
Data Transparency	55	90
Product Traceability	50	92

The outcomes indicate a high level of transparency and traceability. The blockchain system makes transactions visible in an immutable registry where stakeholders can monitor products at each point of supply chain. This minimizes gaps in information and increases accountability (Shaikh et al., 2025).



Compliance and Monitoring Efficiency

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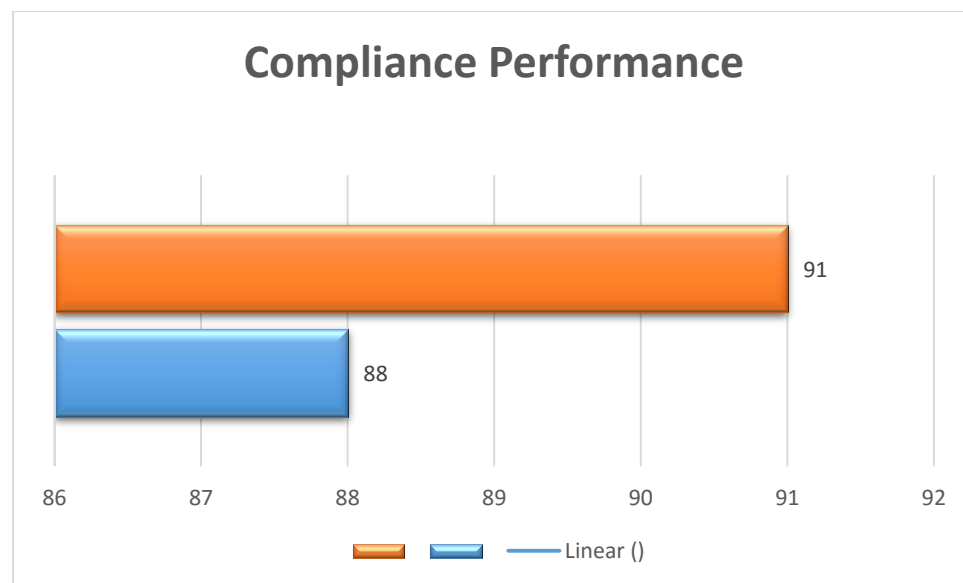
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Table 4.5: Compliance Performance

Indicator	Performance (%)
Automated Compliance Checks	88
Real-Time Monitoring	91

With the help of smart contracts, it is possible to check the compliance of the contract and reduce the number of individuals who must be involved in the process and associated mistakes. The issue of real-time tracking also helps in ensuring the reliability of the system by providing real-time messages of any anomalies and deviation (Al Fotaih, 2025).



Discussion

These research results can be taken as a fine evidence that blockchain technology may influence the change of the pharmaceutical supply chain management of Pakistan by improving the extent of its transparency, traceability, efficiency, and safety. The level of acceptance of stakeholders observed in the results is quite high, that is, it is possible and desirable to adopt blockchain in the industry. The perceived usefulness and trust improvement are the indicators that reflect the significance of blockchain to the situation of overcoming the old issues of counterfeit drugs and accountability. Such findings are consistent with the literature that has offered a crucial role of trust and transparency in blockchain-enabled healthcare-related applications (Shoaib et al., 2025).

The drastic decline in the number of counterfeit drugs provided proves the effective application of blockchain as the means of the authenticity of the products. A traditional system does not have real-time tracking and secure data transmissions of goods that allow counterfeit products to trickle into the supply chain. However, a blockchain-based system has an immutable record and authentication that can be achieved with the assistance of QR codes that seriously limit the possibility of interference and frauds. This highlights the fact that the idea of decentralized systems

can enhance the integrity of the supply chain by providing verifiable and transparent history of transactions.

It is also based on the fact that the blockchain integration enhances efficiency of a supply chain. Traditional supply chains are typified by slowness, ineffective communication and data system. The blockchain platform will be able to address these problems since the data can be shared and synchronized on one platform. This adds speed in decision making, cost cutting in operations and general performance. The results validate the fact that blockchain technology is capable of supporting the processes and enhancing coordination among the parties involved, which is essential in efficient supply chain management.

The biggest gains achieved in this study are transparency and traceability. This implies that it will be possible to track the movement of pharmaceutical products along the supply chain in real time, and this will also ensure accountability and reduce the possibility of mistakes and fraud. This is particularly important in the pharmaceutical sector where the quality and safety of the products is of great importance. The results confirm that blockchain technology can potentially feature end-to-end visibility, meaning the stakeholders will be able to monitor the movement of products and verify their authenticity in real time.

The second component of the discussion is the use of smart contracts in regard to enhancing compliance and monitoring efficiency. Automatic compliance checks reduce the verification done manually and ensures that all transactions are compliant. This improves efficiency, not to mention the fact that it minimizes the risks of human error. The real time monitoring also improves the system as it makes the system provide immediate alert in the event of an abnormality so that measures can be taken promptly. All these features make blockchain a powerful tool in the management of compliance in advanced supply chains.

With the significant benefits of utilizing blockchain technology, there are also some challenges associated with it. One of the biggest obstacles is the initial high cost of deployment, and the fact that the task requires technical expertise. Interoperability and the possibility of integrating with its existing systems can be a challenge to organizations aiming to integrate blockchain with their systems. It is also true that the stakeholders, accustomed to the old way of doing things, might not welcome the change. The most appropriate way to address these problems is appropriate training, sensitization and enabling regulatory measures.

Another thing that needs to be considered is the scalability of the blockchain systems. The greater the number of transactions being considered the higher the need to maintain system performance and efficiency. This issue can be addressed using distributed ledger platforms such as Hyperledger Fabric and its scaled and flexible solutions. However, additional research is needed to try to stream down performance of the systems and capability of blockchain structures to enable operations at scale to perform successfully.

In conclusion, the discussion has shown that blockchain technology can reshape the pharmaceutical supply chains by addressing the key areas of transparency, traceability, and efficiency. The IoT and smart contracts can also be introduced into the system and enhance its potential even more as now it would be possible to track everything and run automatic procedures in real-time. However, the general findings

were that blockchain usage may lead to the much-needed transformation of supply chain operations and make healthcare systems safer and more effective.

Conclusion

Blockchain technology is a disruptive opportunity in the pharmaceutical supply chain in Pakistan to enhance transparency, traceability and trust. This concept or theoretical model shows how a decentralized and unalterable registry system will address solveless issues of fake medications, failure to convey real-time monitoring, data dispersion and lack of regulatory oversight. The proposed framework will offer assurance of authenticity of the products and maximize accountability in the supply chain by enabling it to capture the transactions of all the stakeholders involved in the system like the manufacturers, distributors, regulators and pharmacies permanently and safely.

In addition, the implementation of blockchain may enhance operational efficiencies, delays, and national and international standards. The model is theoretical yet has a strong research foundation which can be empirically tested and applied in the pharmaceutical industry in Pakistan practically.

Recommendations

In order to implement a pharmaceutical supply chain system, which is based on blockchain, successfully in Pakistan, the following recommendations can be offered:

Pilot Implementation Programs

Carry out small scale pilot projects with key stakeholders to find out viability, technical challenges and system functionality before rolling it out at state level. The government should also develop open policies and legal regulations that may help use blockchains, including the data governance, digital signatures, and compliance rates. Encourage the collaboration of pharmaceutical firms, medical homes, regulators, and technology firms to become interoperable and common standards.

Infrastructure Development

Invest in internet infrastructure including internet connectivity as well as secure data infrastructure particularly in inflexible and underserved areas. Carry out stakeholder education regarding the technical expertise and sensitization on how to utilize the blockchain in the supply chain management.

Integration with Existing Systems

Ensure that the blockchain system does not interfere with the current supply chain and regulatory systems so that a smooth transition can be made and minimal disruption can occur. Introduce the strong encryption and access control solutions to ensure the safety of the sensitive information and the patient and business confidentiality. Conduct empirical research to identify the efficiency, scalability, and cost-effectiveness of the suggested model in a real-life setting.

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