Enhancing Pharmaceutical Supply Chains through Blockchain Technology on Hyperledger Fabric Implementation

Poorti Sharma [1*], Syed Sajid Ali Syed Sabir Ali [1]

Abstract

Background: The complexity and dynamism in business environments necessitate the adoption of advanced technologies to enhance supply chain (SC) processes and routines. In the pharmaceutical industry, maintaining high standards of safety and visibility within SCs is critical. Challenges arise from the proliferation of online medical stores and the need for uniform medication safety standards. The shift towards digital SCs has brought about significant changes, demanding improvements in efficiency and transparency. This study explores the potential of Blockchain technology (BcT) to revolutionize SC processes, particularly in the pharmaceutical sector. By integrating BcT, which offers transparency and security, pharmaceutical SCs can address issues related to data integrity, cost management, and operational efficiency. Methods: A qualitative content analysis was conducted to assess the impact of BcT on SC practices using transaction cost economics. The study evaluated how BcT can enhance visibility, reduce transaction costs, and improve the management of pharmaceutical SCs. Hyperledger Fabric, a BcT platform, was used to design and implement a secure medicine distribution system in a smart hospital setting. Results: Implementation of BcT through Hyperledger Fabric demonstrated significant improvements in transaction speed and efficiency. Performance tests showed consistent reaction times and transaction rates even with increasing user loads. For instance, the system maintained a reaction time increase of only 20 milliseconds with 300 users and achieved a mean transaction processing rate of 120 transactions per second with a user group of 300. Conclusion: The integration of BcT in pharmaceutical SCs addresses key issues related to safety, transparency, and efficiency. By utilizing BcT and Hyperledger Fabric, the study provides a robust framework for managing pharmaceutical supply chains, improving data integrity, and reducing transaction costs.

Keywords: Blockchain technology, pharmaceutical supply chain, Hyperledger Fabric, transaction cost economics, digital supply chain, data integrity.

Significance | Digitizing supply chains with Blockchain technology improves transparency, reduces costs, and ensures secure medication distribution, crucial for pharmaceutical safety.

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1. Introduction

As business settings get more complicated and changeable, it is essential to use new technology to improve SC processes and routines. It is important to meet high standards in the pharmaceutical industry, meaning the SC needs to be open and visible. Setting uniform medication safety standards has been hard because there are many online medical stores. As more and more SCs become digital, they are going through a big change (Cole,

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Stevenson, & Aitken, 2019). The digitization of SC is a complex and useful process that uses cutting-edge technology and analysis tools to give businesses new ways to make money and increase their economic value. Digitizing SC helps companies in many ways, like lowering costs, improving quality, increasing sales income by expanding market share, making goods that focus on customers, and getting a strategic edge that improves total business processes (MacCarthy & Ivanov, 2022). Many people are interested in this particular case of BcT applications in the SC. So, adding BcT to SC processes could greatly improve total performance. Businesses have already started using BcT in all their SCs (Bischoff & Seuring, 2021). BcT has the benefit of making a reliable and safe system that ensures data is clear and can't be changed (Neelima, Govindaraj, Subramani, ALkhayyat, & Mohan, 2024). In addition, IC makes operations more efficient. BcT could help SCs by clarifying all data, lowering costs and risks, and making operations more sustainable (Saberi, Kouhizadeh, Sarkis, & Shen, 2019). Because it can make supply chain management (SCM) methods more effective and flexible, BcT has a lot of promise for use in the pharmacy industry. Supply networks that aren't working well can hurt a company's image and make customers unhappy. Pharmacies, hospitals, and people looking for medical care are just some places where PSC sends medicines. Due to the ongoing COVID-19 outbreak and the lack of medication sources, PSC has become a major worry for many countries (Ghadge, Bourlakis, Kamble, & Seuring, 2023).

Furthermore, the delicate nature of pharmaceutical items necessitates the implementation of precise protocols to safeguard medical supplies from any potential injury caused by fluctuations in temperature. To avoid any interference or deterioration in the patient's recovery, regulatory authorities that oversee pharmaceuticals' safety, quality, and efficacy impose stringent standards on those involved in patient safety and care. Nevertheless, despite the stringent regulations imposed by regulatory authorities, the number of counterfeit drug cases continues to increase (Oh, Choi, & In, 2023). Medicine fraud is a pressing concern in developing nations because of their lower wealth, often weaker regulatory systems, and greater levels of corruption. According to the World Trade Organization, around 10% of the pharmaceuticals marketed in Egypt are counterfeit. BcT can effectively address the problem of limited transparency and visibility in PSC (Ghadge et al., 2023).

2. Related Works

BcT may have an impact on transaction costs within the Egyptian pharmaceutical business. The authors Schmidt and Wagner (2019) have previously examined BcT applications from the standpoint of transaction cost economics (TCE). Research suggests that using BcT in a SC allows for all participants' seamless updating, integration, and participation. Furthermore, it has been shown that using BcT may lead to a reduction or complete elimination of transaction costs (Queiroz, Telles, & Bonilla, 2020). Nevertheless, the existing body of research lacks comprehensive empirical proof of the correlation between BcT-based SC applications and the associated contract charges. This article employs a qualitative content investigation methodology to evaluate the impact of deploying digital technology on SCM practices and how these impacts may be explained using transaction cost theory (Mohamed, Nijaguna, Pushpa, Dayanand, Naga, & Zameer, 2024). In today's business landscape, the significance of SC complexity has grown considerably compared to a decade ago.

Consequently, the need for visibility in SCs that are accessible, trustworthy, and secure has become more crucial. Furthermore, this escalating intricacy impacts the price of products and their accessibility to customers. The progress in information systems and the development of BcT have transformed the conventional approach to medication SCs in healthcare, replacing it with secure automated solutions (Hasselgren, Kralevska, Gligoroski, Pedersen, & Faxvaag, 2020). One option for enabling a software platform without trusting on a trusted third party is to use Hyperledger Fabric and IC. A recent technology that utilizes standard programming languages for IC is the open-source Hyperledger Fabric, known for its modular design (Guerraoui, Kuznetsov, Monti, Pavlovič, & Seredinschi, 2019). This offers extensive opportunities for product-centric business systems. This article primarily discusses designing and implementing a secure medicine distribution system in a smart hospital (Sindhusaranya, Yamini, Manimekalai, & Geetha, 2023). The system is built on BcT and utilizes Hyperledger Fabric. The solution will demonstrate the use of Hyperledger Fabric technology in using BcT to securely distribute and manage medicine delivery records across various departments inside the hospital.

Implementing BcT in the pharmaceutical business may have a substantial effect. The authors in Tapscott and Tapscott (2018) show how technology may facilitate information interchange across several processes and reduce transaction costs associated with contractual difficulties connected to confidentiality. Active cooperation facilitated by BcT enhances trust and integrity among many stakeholders. Authors in Sylim, Liu, Marcelo, and Fontelo (2018) show that using a surveillance BcT would enhance transparency and accountability for all participants in the industry. Authors Hasselgren, Kralevska, Gligoroski, Pedersen, and Faxvaag (2020) have identified electronic health records as the primary focus for using BcT to enhance healthcare operations and services. They researched how BcT might fulfill the needs of cold PSC by ensuring digital identification, identification and traceability, data reliability, transparency, and waste control (Kodric, Vrhovec, & Jelovcan, 2021). In a recent study, Badhotiya et al. (2021) showed that BcT can enhance confidence and openness in the pharmaceutical

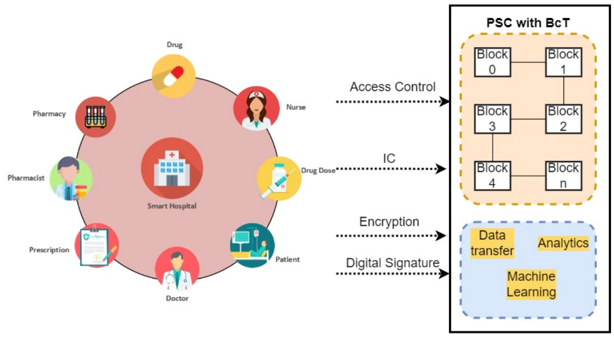

Figure 1 Overview of PSC management in a medical BcT

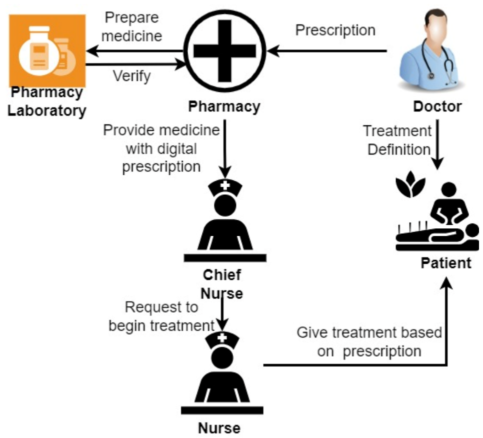

Figure 2 Flow of PSC management

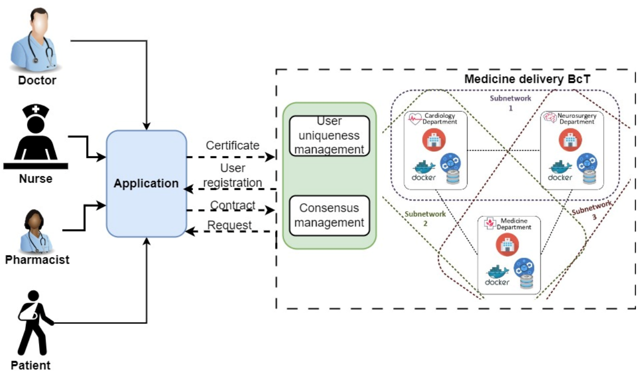

Figure 3 Proposed BcT-based framework for managing the PSC

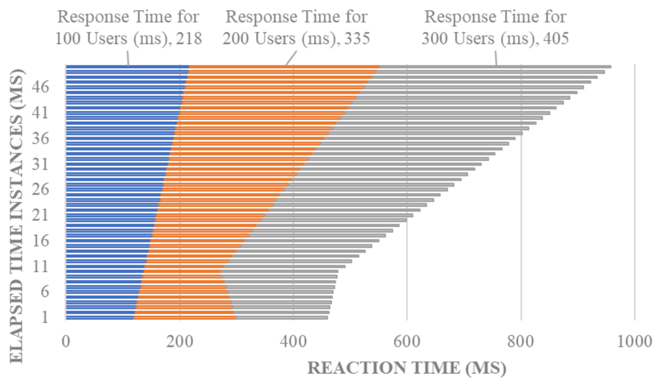

Figure 4 Reaction time (ms) for different users

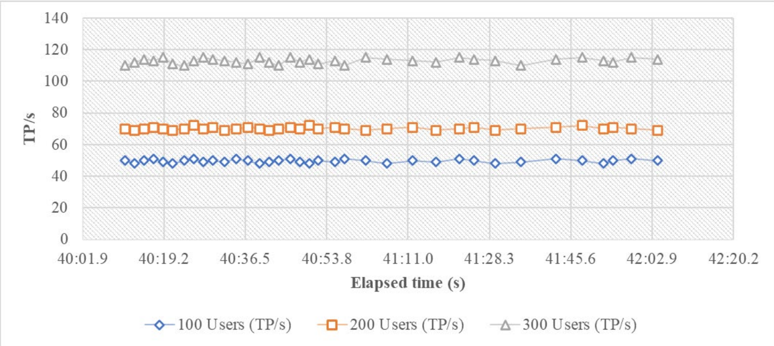

Figure 5 Elapsed time versus transactions processed per second.

industry by documenting transactions across different entities. Although there is growing interest in PSC, it is evident that this technology is not widely used, particularly in the context of underdeveloped countries. To chart the current state of research in PSC, one may use the established framework for BcT in SC, as outlined in Pournader, Shi, Seuring, and Koh (2020). The four distinguished clusters are technology, confidence, trade, and traceability. The technology focuses on addressing links and privacy concerns. Trust involves decentralizing SC information and offering proof of uniqueness for SC transactions. Trade encompasses money transactions and SC financial services. Transparency ensures resilient SC operations, goods traceability, and protection.

3. BcT in Ensuring the Integrity of PSC

The distinct decentralized distributed technology of BcT has changed the medical sector. Figure 1 illustrates the suggested PSC management scenario that utilizes BcT. The graphical representation depicts a medical BcT that oversees and maintains the whole SC, holding data about drugs, pharmacies, pharmacists, medical prescriptions, doctors, patients, nurses, and medication dosages—the medication delivery data functions as an independent repository, sometimes known as a stored-off BcT. Data analytics is a valuable tool for analyzing, visualizing, and reporting health information. Hospitals and other healthcare-related firms relying on health information for daily operations would find it advantageous. Moreover, physicians can access patient data upon receiving the patient's consent, and patients may also choose to share their information with any doctor on the network. The access control rule in the IC may be defined to establish permissions, ensuring the confidentiality and authenticity of patients' data.

The scheme consists of dependable nodes that execute a consensus process to ensure the reliability of the distributed ledger (DL). At first, the doctor thoroughly inspects the patient and determines a treatment plan, including the appropriate dosage of medication and other recommendations, which are then provided using a Digitized Prescription (DP). Next, the DP is sent to the pharmacist, who assess the legitimacy of the prescription and instruct the pharmacist to assemble the medication list. Subsequently, the pharmacist dispatches the medication to the pharmacist for meticulous comparison with the DP. The assembled medication cart and the DP are sent to the chief nurse, who confirms and upgrades the pharmacy's pharmaceutical stock and instructs the nurse to begin the patient treatment protocol. Ultimately, the nurse or care taker carries out the treatment for the patient as directed by the doctor's prescription. Figure 2 displays the comprehensive framework of the proposed PSC management.

The main objective of a BcT is to archive data in a decentralized way. Each block consists of a series of transactions that are hashed and encoded. Figure 3 illustrates the proposed BcT-based framework for managing the PSC. The application uses a user service architecture with an IC and a DL as middleware. The proposed PSC-BcT involves the transmission of transaction proposals by users (such as doctors, nurses, pharmacists, and patients) through the application. These proposals are used to access various backend services, including prescription, identity administration, booking appointments, digital drug records (DDR), exchange of data, and managing pharmacies. The proposed BcT offers these services. The BcT transaction supports CRUD (create, read, update, and delete) activities, facilitating data transformation across interconnected nodes. However, for transactions that need privacy and security, we propose the notion of a subnetwork to divide the whole BcT into a distinct private BcT network. The primary objective of this exclusive network is to securely distribute sensitive information only to the relevant department while preventing access by other departments. The suggested medication delivery system enables individual departments to establish subnetworks to facilitate secure data exchange.

The distinguishing characteristic of the proposed BcT scheme is its use of a consent network, setting it apart from existing BcT-based systems. This feature enables exclusive participation and enrollment of authorized participants in the BcT via a user uniqueness manager (UUM). The UUM issues credentials for user registration and validation. Furthermore, these facilities pertain to the authentication, verification, and creation of digital signatures for each user involved in the BcT network. Consensus management establishes a consensus between a section and a subnetwork by using a supplied interface and managing the contract sequence. Every division inside a medication distribution BcT consists of nodes and a DL. The node can store data and includes an IC that is accountable for approving the contract request or writing a contract block to the ledger. The consent method's objective is to guarantee a solitary and genuine history of transactions, devoid of any unacceptable or contradicting transactions. The DL system maintains a permanent and easily visible log of every transaction, logs, and archive of events and acts inside the network. To ensure the uniformity of each ledger, many cryptographic and consensus procedures have been used, such as digital signatures and hashes.

4. Results

Hyperledger Fabric, a freely available performance benchmark tool, has been utilized to evaluate the efficiency of a BcT system [15]. The Hyperledger Fabric project, initiated by the Linux Foundation, aims to evaluate and compare the performance of various BcT implementations.

Figure 4 compares three distinct user groups to examine the reaction time of the projected PSC- BcT system. The simulation was conducted for a duration of 50 milliseconds. Typically, the system's reaction time grows as the number of users simultaneously requesting the system increases. The user groups were divided into three different types: initially, there were 100 users in the initial round, followed by 200 users in the subsequent round, and finally, the performance was assessed with an increased user count of 300. Figure 4 depicts the system's reaction for the first two categories, which are almost identical. However, when the number of users is increased to 300, the reaction rate only rises by 20 ms for the first 200 transactions. Despite the growing users, the system's reaction time stays consistent.

Figure 5 examines the rate at which transactions are processed per second (TP/s). Like Figure 4, it has been used an equivalent number of user sets to assess the TP/s of the proposed PSC-BcT system. Typically, when a single user sends a request to the server and receives a response after 50 ms, and the TP/s may are computed. Figure 5 demonstrates that the user set of 100 users achieves a mean of 35 TP/s during 200 seconds. Nevertheless, as the number of users is augmented, the TP/s likewise escalates. For a group consisting of 200 members, the TP/s is 65. This value changes as the group size increases to 300 users. The mean TP/s is 120, with a total duration of 100 seconds.

5. Conclusion

The integration of Hyperledger Fabric into pharmaceutical supply chains demonstrates a significant advancement in securing and managing medication distribution. By employing BcT, the proposed system effectively mitigates issues related to counterfeiting and transaction inefficiencies. Results indicate that the system maintains robust performance even as user load increases, with transaction processing speeds improving as user numbers rise. This approach not only enhances data security and traceability but also supports the establishment of a more resilient and transparent PSC, addressing critical challenges in pharmaceutical safety and operational effectiveness.

Author contributions

PS and SSASSA were responsible for conceptualization, fieldwork, data analysis, original draft writing, editing, funding acquisition, and manuscript review. PS and SSASSA focused on research design, methodology validation, data analysis, visualization, manuscript review, and editing. Additionally, PS handled methodology validation, investigation, manuscript review, funding acquisition, supervision, and editing. All authors have approved the manuscript after reviewing the final version.

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Competing financial interests

The authors have no conflict of interest.

References

Badhotiya, G. K., Sharma, V. P., Prakash, S., Kalluri, V., & Singh, R. (2021). Investigation and assessment of blockchain technology adoption in the pharmaceutical supply chain. Materials Today: Proceedings, 46, 10776-10780.

Bobir, A. O., Askariy, M., Otabek, Y. Y., Nodir, R. K., Rakhima, A., Zukhra, Z. Y., & Sherzod, A. A. (2024). Utilizing deep learning and the Internet of Things to monitor the health of aquatic ecosystems to conserve biodiversity. Natural and Engineering Sciences, 9(1), 72-83.

Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: Implications for operations and supply chain management. Supply Chain Management: An International Journal, 24(4), 469-483.

Ghadge, A., Bourlakis, M., Kamble, S., & Seuring, S. (2023). Blockchain implementation in pharmaceutical supply chains: A review and conceptual framework. International Journal of Production Research, 61(19), 6633-6651.

Guerraoui, R., Kuznetsov, P., Monti, M., Pavlovič, M., & Seredinschi, D. A. (2019, July). The consensus number of a cryptocurrency. In Proceedings of the 2019 ACM Symposium on Principles of Distributed Computing (pp. 307-316).

Hasselgren, A., Kralevska, K., Gligoroski, D., Pedersen, S. A., & Faxvaag, A. (2020). Blockchain in healthcare and health sciences—A scoping review. International Journal of Medical Informatics, 134, 104040.

Kodric, Z., Vrhovec, S., & Jelovcan, L. (2021). Securing edge-enabled smart healthcare systems with blockchain: A systematic literature review. Journal of Internet Services and Information Security, 11(4), 19-32.

MacCarthy, B. L., & Ivanov, D. (2022). The digital supply chain—Emergence, concepts, definitions, and technologies. In The digital supply chain (pp. 3-24). Elsevier.

Mohamed, K. N. R., Nijaguna, G. S., Pushpa, Dayanand, L. N., Naga, R. M., & Zameer, A. A. (2024). A comprehensive approach to a hybrid blockchain framework for multimedia data processing and analysis in IoT-healthcare. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), 15(2), 94-108. https://doi.org/10.58346/JOWUA.2024.I2.007

Neelima, S., Govindaraj, M., Subramani, K., ALkhayyat, A., & Mohan, C. (2024). Factors influencing data utilization and performance of health management information systems: A case study. Indian Journal of Information Sources and Services, 14(2), 146-152. https://doi.org/10.51983/ijiss-2024.14.2.21

Oh, J., Choi, Y., & In, J. (2023). A conceptual framework for designing blockchain technology enabled supply chains. International Journal of Logistics Research and Applications, 26(10), 1315-1333.

Pournader, M., Shi, Y., Seuring, S., & Koh, S. L. (2020). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. International Journal of Production Research, 58(7), 2063-2081.

Pournader, M., Shi, Y., Seuring, S., & Koh, S. L. (2020). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. International Journal of Production Research, 58(7), 2063-2081.

Queiroz, M. M., Telles, R., & Bonilla, S. H. (2020). Blockchain and supply chain management integration: A systematic review of the literature. Supply Chain Management: An International Journal, 25(2), 241-254.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117-2135.

Schmidt, C. G., & Wagner, S. M. (2019). Blockchain and supply chain relations: A transaction cost theory perspective. Journal of Purchasing and Supply Management, 25(4), 100552.

Sindhusaranya, B., Yamini, R., Manimekalai, M. A. P., & Geetha, K. (2023). Federated learning and blockchain-enabled privacy-preserving healthcare 5.0 system: A comprehensive approach to fraud prevention and security in IoMT. Journal of Internet Services and Information Security, 13(4), 199-209.

Sylim, P., Liu, F., Marcelo, A., & Fontelo, P. (2018). Blockchain technology for detecting falsified and substandard drugs in distribution: Pharmaceutical supply chain intervention. JMIR Research Protocols, 7(9), e10163.

Tapscott, D., & Tapscott, A. (2018). How blockchain will change organizations